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THESIS

**NUCLEAR ELECTRIC GENERATION:
POLITICAL, SOCIAL, AND ECONOMIC
COST AND BENEFIT
TO
INDONESIA**

by

W a l i y o

December, 1994

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Peter R. Lavoy

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NUCLEAR ELECTRIC GENERATION: POLITICAL, SOCIAL, AND ECONOMIC COST AND BENEFIT TO INDONESIA

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

Indonesia, the largest archipelagic country with a population the fourth biggest in the world, is now in the process of development. It needs a large quantity of energy electricity to meet the industrial and household demands. The currently available generating capacity is not sufficient to meet the electricity demand for the rapidly growing industries and the increasing population.

In order to meet the future demand for electricity, new generating capacity is required to be added to the current capacity. Nuclear electricity generation is one possible alternative to supplement Indonesia's future demand of electricity. This thesis investigates the possibility of developing nuclear electricity generation in Indonesia, considering the political, social, and economic cost and benefit to Indonesia.

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I. INTRODUCTION

A. GENERAL

Indonesia is a large country with the fourth largest population in the world. In the process of its development, switching from agricultural to industrial society, Indonesia requires a large amount of electric power which is not met by currently available generating capacity. Fast growing industries as well as increasing populations, cause the demand for electricity to increase very rapidly, especially on Java island. This demand grew about fifteen percent annually during the 1970s to 1980s, but it has decreased to nine percent in 1993 (National Development Information Office, 1993). Of the total electric power generated throughout the country, the industrial sector consumes about fifty nine percent, while the other forty one percent is utilized by household utilities. The demand for electricity, in the private sector, has never been met by the State Electric Company (PLN). Some industries and companies provide for their own demand of electric power with privately owned power plants. Most of these power plants are employing oil as a source of energy generators.

Indonesia has an abundance of resources which can be developed as a source of energy generator such as water, volcanoes, oil, coal deposit and natural gas. Various technologies of electricity generation have been implemented in Indonesia to meet its current demand for electricity, hydro power plants, geothermal, coal and oil-fired power plants as well as solar shell type power generation. Diversification of electricity power generation is needed to reduce dependency on any source of energy. But the most economical way of producing electricity with the least damage to the environmental and meeting concerns of public safety has become one of the most interesting and specific attentions of the government, as particularly related to the using nuclear energy.

The electricity generation system of Indonesia relied heavily on oil type generation until the early 1980s. Since then, the government has paid more attention to other alternatives and began to extend the development of non oil-types of electricity generation, while maintaining oil and natural gas as the major source of export

commodities. Based on the government's energy policy, the development of electricity generation must be looking for the least cost of alternatives with a high reliability of supplying energy and with the least environmental damage or threat to public safety. To meet this requirement, the employing of "technology-intensive" alternatives would be the better option rather than the "resource-intensive" alternatives. Therefore, the maximum production of electric power can be achieved within the national budgetary constraint, and low-cost of produced electricity can be affordable for public households and industries. By producing low-cost electricity, people may enjoy the benefits without any threat of environmental damage or to public safety.

Hydroelectric power provides the least environmental effect, and provides benefit such as irrigation, water supply resource, and controlling flood. But hydroelectric power may cost more than the other types of electricity generation. One consideration in developing hydroelectric power plants would be the problem of finding the suitable sites for generating economic electricity and sites for transmission network. Most potential sites for hydroelectric generated electricity may already have been exploited.

Another alternative is the possibility of implementing nuclear fission technology which has been developed by many countries. This option needs to be carefully examined, because nuclear fission for electricity generation has potential threat to public safety, and the uncertainty of risk has become a source of public concern and political debate both national or internationally. The probability of releasing a large quantity of radioactive material from accidents or sabotage, even though it is very small (Barrager, Judd, North, 1976) will still exist because of the nature that human beings are not free from error when designing nuclear facilities. Consequently, the nuclear states industries have been continually conducting design improvements to promote public safety, and reduce its capital cost to assure public acceptance.

The management of nuclear wastes and the spent fuel which is removed from the reactor core, as well as plutonium at recycling plants, will create serious problems and potential threat from plutonium diversion or theft. Moreover, the radioactivity of the nuclear waste will persist for thousands of years, which may endanger future generations.

Generally speaking, nuclear industry as a whole still faces an economic challenge and public acceptance. The conflict between those who support nuclear generated electricity and nuclear generation opponents has existed for many years and yet the debate has not been resolved. The promise of economic and safe technology of nuclear electricity generation is questionable and need further examination. Cost of the plant and its operation, and other factors associated with nuclear power plants such as; the availability of fuel, the reliability of its source of supply, and possible effect of employment must be carefully deliberated before making a decision for nuclear electricity generation.

Before embarking on technology of nuclear electricity generation, a thorough study and assessment on various aspects and the preparation associated with nuclear power should be conducted to determine whether or not nuclear power is feasible for development in Indonesia. This study should determining suitable sites, finding a source of uranium ore deposit, the possible effect to the environment, the safety regulatory, personnel training and expertise, the development of nuclear power plants, and finally the management of nuclear electricity generation as a whole. Finally, the correct decision on selecting the best type and the size of reactor capacity to meet the national budgetary constraint and availability of other resources that will provide economic benefit and improve standard of living throughout the Indonesian societies.

B. SCOPE OF THE THESIS

To meet the demand for electricity, there are some possible options of electricity generation which may be developed in Indonesia. Each option may have different impacts on the society in terms of economic cost and benefit, social cost and environmental effect as well as political problems. In order to provide the correct choice for producing electricity, this thesis will focus on the possibility of developing nuclear electricity generation in Indonesia, and whether or not nuclear electricity generation is a viable option to supplement the future requirement of Indonesia's electricity demand.

In specific, this thesis will evaluate various problems dealing with the nuclear electricity generation in Indonesia, such as:

- What are the international political aspects of having nuclear electricity generation in Indonesia?
- Is the nuclear electricity generation an appropriate option, taking into account the cost and benefit to Indonesia?
- What are the effects of nuclear electricity generation to the environment, and what is the social cost to the society?
- What type or size of reactors is suitable to be built in Indonesia, considering the various factors and resources available in this country?

C. PURPOSE OF THE THESIS

The purpose of this thesis is to evaluate various factors and resources available in this country which are relevant to the nuclear electricity generation program, and to determine the most economical way of generating electricity in Indonesia. This thesis will also provide the Indonesian government with information dealing with nuclear electricity generation, such as: the international political aspects, social cost to the society, and economic cost as well as the benefit for developing the energy plant that meets the electricity demands in the future.

D. METHODOLOGY

This research effort will evaluate the data provided from various sources using an economic theory approach with emphasis on the cost and benefit analysis of having nuclear electricity generation by comparing the cost of nuclear and non-nuclear electricity generation. Coal-fired electricity generation is used in the comparison of the cost, because those two different types of electricity generation nuclear and coal produce the most comparatively economical generation of low cost of electricity.

While gas-fired is used in the preliminary study in comparing these two options, it would require further evaluation and assessment to become a viable alternative of electricity generation other than nuclear power plants.

This research will be conducted mostly through review of current books, periodicals, articles, journals, and Indonesian Government's Strategic Plans and policy guidance, as well as the feasibility study reports on nuclear power plant project which has been done in the past by various agencies, with the assumption that the current situation does not change.

E. ORGANIZATION

This thesis is organized into seven chapters. Chapter I is the introduction. It will introduce and give an overview of nuclear electricity generation in general, and the problems dealing with nuclear power, scope of the thesis, purpose of the thesis, methodology used on research, and the organization of the thesis.

Chapter II is a background and overview of Indonesia. It discusses resources availability and the related factors to the energy generation, includes geography, climate, populations, natural resource, economy, human resource and infrastructure, which must be evaluated as to whether or not they are able to support a nuclear electricity generation program in Indonesia.

Chapter III discusses the international political aspects of nuclear power plant including public opinions on economic and environmental issues, the relationship of nuclear industry and nuclear weapon, nuclear power safeguard, and management of spent fuel including surplus of plutonium etc.

Chapter IV discusses the economic cost associated with the nuclear fuel cycle, which includes the cost of generation. This cost covers all the cost associated with the production of electricity, and the cost of decommissioning of the plant facility of nuclear electricity generation.

Chapter V discusses the economic benefits to Indonesia of developing a nuclear power plant.

Chapter VI discusses the environmental effects and social cost of nuclear fuel cycle to the society.

Chapter VII provides a summary and conclusion of the overall study and gives recommendations to the government in making an appropriate decision on nuclear power. This chapter will consider whether or not nuclear electricity generation is possible in Indonesia, and a viable supplement for Indonesia's future requirements for electricity generation.

II. BACKGROUND AND OVERVIEW

A. GENERAL

This chapter discusses various factors that may affect the possibility of developing nuclear electricity generation in Indonesia. The data provided in this chapter will give an overview of the availability of resources which may support the nuclear program, whether or not they meet the requirement needed to build a nuclear power station in Indonesia. The availability of resources in Indonesia will have an impact to the development of nuclear electricity generation.

1. Geography

Indonesia is the largest archipelagic country in the world, situated in the cross position between Asia and Australia continents, and between Pacific and Indian oceans. It consists of about 13,667 islands and covers the land of about 1.91 millions square kilometers and water territorial nearly four times of the land size (National Development Information Office, 193; Indonesia a Country Study, 1993). It stretches along the equator, about 5,120 kilometers from east to west, and 1,760 kilometers from north to south. The five biggest islands are Java, Sumatra, Kalimantan (Southern part of Borneo island), Sulawesi (Celebes), and West Irian (Western part of Papua New Guinea).

From those 13,667 islands, are grouped into two major groups of islands:

- Greater Sunda island includes Sumatra, Java, Kalimantan, and Sulawesi.
- Lesser Sunda island covers Maluku (Moluccas), Nusa Tenggara Islands and West Irian.

Two shelves are also found in Indonesia territory; Sunda shelf includes island of Sumatra, Java and Kalimantan, and Sahul shelf is found between Moluccas and West Irian.

Throughout these islands there are mountains and about 400 volcanoes, of which about 100 are active. Two world record violent volcano eruptions have been experienced in this area. First, in 1815 the Gunung Tambora (Mt. Tambora) eruption, on Lombok

island, in the province of Nusa Tenggara. The second was the Krakatau eruption in 1883, in the west part of West Java province (Indonesia a Country Study, 1993).

Indonesia has four times as much water area as land area. For this reason, Indonesia also tectonically unstable and many earthquakes have been experienced throughout the islands. The last earthquake combined with powerful tidal wave took place in December 1992 on Flores island, killed more than 2000 people (Caraka Warta, June 1994).

The geographical uniqueness of Indonesia, which has a potential natural disaster such as earthquake, volcano eruption, tidal wave, and flood, will influence the decision making on nuclear power plant program. The effect would be on the design requirement, size of reactor, or type of the reactor which is suitable for construction in Indonesia, will in turn have a major impact on costs of the nuclear electricity generation program in Indonesia.

2. Climate

Most of Indonesia lies directly along the equator, this gives the country a tropical climate, characterized by wet and dry season period. The temperature ranges from about 25 to 35 degrees Celsius, and humidity ranges from 75 to 90 percent. Winds are moderate throughout the country, and the rain fall averages to 706 millimeters yearly.

3. Population

The Indonesia's population is estimated roughly at 190 million, making it the fourth largest population in the world, after China, India, and the United States. The population is concentrated most heavily on the fertile islands of Java, Madura, Bali, where the population density on those islands exceed 1,000 people per square kilometers. On Java itself, about 60 percent of total Indonesia's population live which makes Java the most populated island in the world.

The majority of Indonesia's population is Malay extraction, and about 300 ethnical groups exist and some 300 languages and dialects are spoken throughout the country. Approximately eighty five percent of the population is Muslim, about ten percent is Christian, and the remaining five percent are a mixture of Hinduism and Buddhist.

The diversity of people with various cultural backgrounds and education level in Indonesian society, make it different to handle the nuclear problem. Information dealing with the danger of nuclear technology as well as its benefit to the people should be widely spread and disseminated to the people throughout the country.

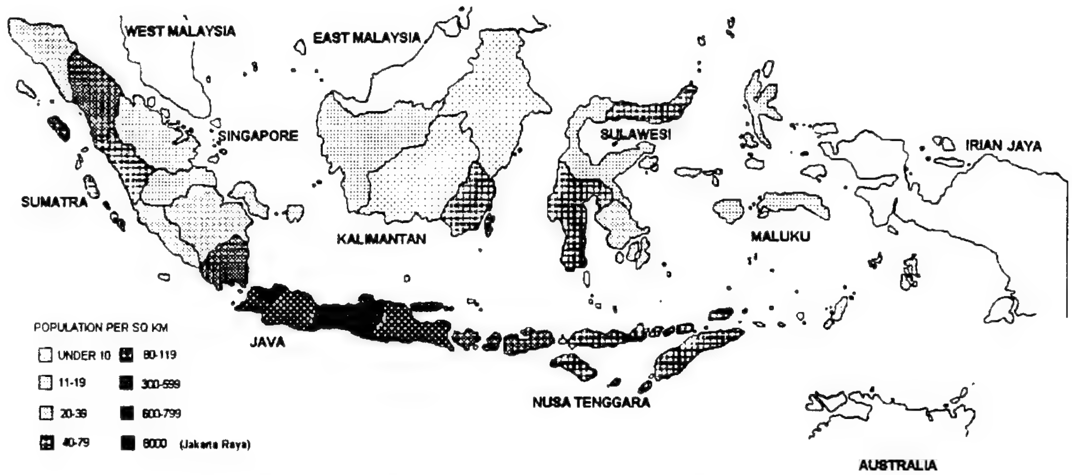

Figure 1. Demographic Map of Indonesia.

4. Natural Resources

Indonesia is rich in natural resources like oil, coal, natural gas, tin, copper, nickel, bauxite, gold, silver and kaolin and small deposits of uranium are also found in Indonesia.

a. Oil

Indonesia is the fifteenth largest oil-producing country in the world. It also is a member of OPEC and Indonesia is responsible for six percent of total OPEC's production, and accounts for 80 percent of all oil production in South East Asia.

b. Natural Gas

The natural gas reserves throughout the country are estimated to be 104 trillions scf (standard cubic feed) with average production of 2.67 trillions scf (in 1992). From the total production, 78 percent is exported to Japan, and the rest of exports are to Korea and Taiwan. Indonesia also produces 2.6 million metric tons of LPG (Liquified Petroleum Gas) annually (National Development Information Office, 1993).

c. Coal

The total coal resources of Indonesia are estimated to be 32 billion tons. At this time, about 750 million tons are being exploited. The current production is 23.4 million tons annually, and the production is estimated to increase to thirty million tons in 1995. By the year 2000, the coal production is projected to be forty eight million tons per annum (National Development Information Office, 1993). The Indonesia's coal is considered high quality because it contains less than one percent of ash and can produce 25 Giga Joules per ton, this lessens the requirements for pollution control. Therefore, coal-fired electricity generation will provide more benefit due to lower cost of controlling environment.

d. Uranium

A recent study conducted by the National Atomic Agency (BATAN), reported that some uranium deposit was found in Sumatra and Kalimantan islands. Though the amount of predicted deposits are small, and mining has not yet been exploited, extensive exploration should be carried out to find other possibility source of uranium deposit throughout the islands.

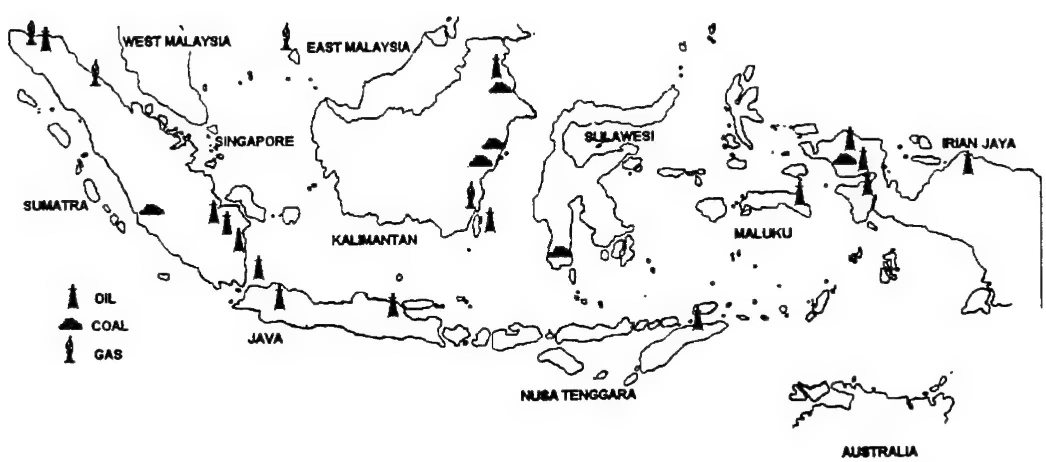

Figure 2. Indonesia's Oil, Coal and Gas.

B. ECONOMY

Indonesian economy was inherited from the Dutch Colonial rules, an economy based on small holder agriculture. After Dutch Colonial rule, Indonesia possessed a well-developed plantation system such as tea, coffee, palm oil, tobacco, rubber etc., also some fledgling petroleum industry, tin mining, and simple manufacturing capabilities providing basic consumer products for the domestic market. Until the first two decades after independence, the Indonesian income per capita was noted to be less than \$ 70, and the country faced the problems of food-insufficiency.

In the early 1970s, Indonesia started to improve its economy by setting up new economic development programs, implementing new technologies in various industrial sectors and agriculture and inviting foreign investors to invest their capital in Indonesia. The result of the new programs was remarkably good. The economy has improved with average growth rate of seven percent in the 1970s, marked by an oil boom during this period.

The manufacturing sector has most relative economic importance both in job creation and wealth generation. Manufacturing ranging from capital intensive products such as in steel and cement industries, to labor intensive products such as garment and footwear which have led to the GDP growth of 8.5 percent from 1992 through 1994 (National Development Information Office, 1993).

Agriculture is another important sector in economic development. It accounts for about 49.9 percent of total labor force since 1970s. However, it has been declining steadily over the years due to large growth industries. The agriculture sector now contributes about 20 percent to the total national GDP. The development of the agricultural sector has improved, and Indonesia reached self-sufficient in the food production in the mid 1970s.

The oil and gas industries play the most important role in Indonesia's economy. This sector accounted for 31 percent of total national export earning. Since the decline of oil price, the oil and natural gas industries have undergone relative decline in economic importance, and non oil related industries have taken over.

The economic development programs in various sectors such as industries and agriculture, have improved the economic growth to 7.5 percent in 1993, with the income per capita increase to U.S. $ 650, and by the year 2000 is expected increase to U.S. $ 1000.

C. HUMAN RESOURCE

1. Labor and Employment

The large Indonesia's population creates a challenge of employment for constantly growing labor force. Like other developing countries, Indonesia is still facing the problem of unemployment, however, the long-term economic development program has reduced unemployment from 3.6 million in 1971 to 2.3 million in the year 1990. The fast growing industry and services have created new jobs and transfer of labor force from agriculture to the industrial and service sectors. Agricultural sector has accounted for 49.9 percent of the total labor force while industrial and the service sectors account for 50.1 percent (Indonesia a Quarter Century of Progress, 1993).

2. Education

Education receives high priority in the national development program. The government has prioritized education on elementary school, and education is now compulsory for the grades six to nine. The educational program has increased the literacy rate of the urban society to 92.4 percent and the rural population by 80.3 percent in the year 1990 census. The literacy rate of the whole nation including urban and rural societies was noted to be 86.4 percent.

Today, every province has at least one university and throughout the country at least 500,000 students graduate annually from universities and other higher learning institutions. University enrollment reached 1.8 million in 1992. University enrollment is decreasing by eight percent yearly due to the success of birth control for the past two decades. By the year 2000 the government predicts that 3.9 million students will receive university degrees yearly (National Development Information Office, 1993). In response to the nuclear electricity development, the National Atomic Energy Agency has

extensively conducted a research and training program at the various nuclear research facilities at three universities, namely as: Gajahmada University which offers under graduate degrees in nuclear physics; Bandung Institute of Technology which offers under graduate and graduate degrees in nuclear science; and Indonesia University which offers under graduate degrees in nuclear physics. While the doctorate degree of nuclear science is conducted overseas.

Indonesia has currently three nuclear research reactors, with different capacities, those are:

- Reactor Triga Mark II with one megawatt (MW) capacity, located in Bandung Institute of Technology.
- Reactor Kartini with 0.1 megawatts (MW) capacity, located in Yogyakarta Gajahmada University.
- Reactor Siwabessy with thirty megawatts (MW) capacity, located in Serpong.

These reactors have been used to produce the radioisotopes needed for research in the study of and scientific development of various sectors including medical, agriculture, food production and industrial development. The reactors are also used to train the people to deal with nuclear technology and to acquire nuclear expertise. The reactor Triga Mark II in Bandung is used for scientific research in physics, and biology. The reactor Kartini in Yogyakarta is used for education and training for the people to become nuclear operators, and for students conducting research. The reactor Siwabessy in Serpong is used for multi-purpose studies, and will be the center of research of nuclear development. This facility is also projected to become a nuclear fuel fabrication when Indonesia decides to build nuclear reactor for electricity generation.

Nuclear electricity generation in Indonesia has been anticipated since the 1960s. There is now enough expertise in reactor operation, after more than two decades study and training in nuclear technology to realize nuclear electricity generation. At the time when nuclear electricity generators begins operating, Indonesia will have its own expertise and will not be totally dependent upon foreign expertise.

3. Transmigration

Indonesia's population is concentrated heavily on Java, Madura, and Bali islands. The population density on these islands has reached more than 1,000 people per square kilometers (National Development Information Office, 1993). This makes these islands over populated and also limits land use, as well as limits job available for population. To overcome this problem, the government has implemented a transmigration program to balance the population and labor force among the islands, by creating new agricultural areas, and also to promote agricultural production. For the last 25 year period of national development, some 1.7 million families have been resettled to the islands of Sulawesi, Kalimantan, Irian Jaya, and Sumatra.

The distribution of population to various islands reduces the population density on Java and Bali island, which then result in more balance of the population density. Hence this indicates that it would be appropriate to have a balance in the number of nuclear electricity generation facility in other islands, and that nuclear power generation capability need not be concentrated on Java island. Considering the potential risks of nuclear power plant facilities, it is not advisable to build a large capacity nuclear power plant on Java with its over-crowded population.

D. INFRASTRUCTURE

1. Energy

Indonesia has abundance of natural resources which can be developed to provide diverse mix energy sources. Over the past two decades, the energy requirements have been met largely by relying on oil. Most of electricity production in the country was generated by oil-fired power plants. Until the year 1983/1984 oil-fired and gas power plants accounted for nearly 85.6 percent of installed capacity, as shown in Figure 3, 75 percent of all electricity produced by the State Electric Company (National Development Information Office, 1993).

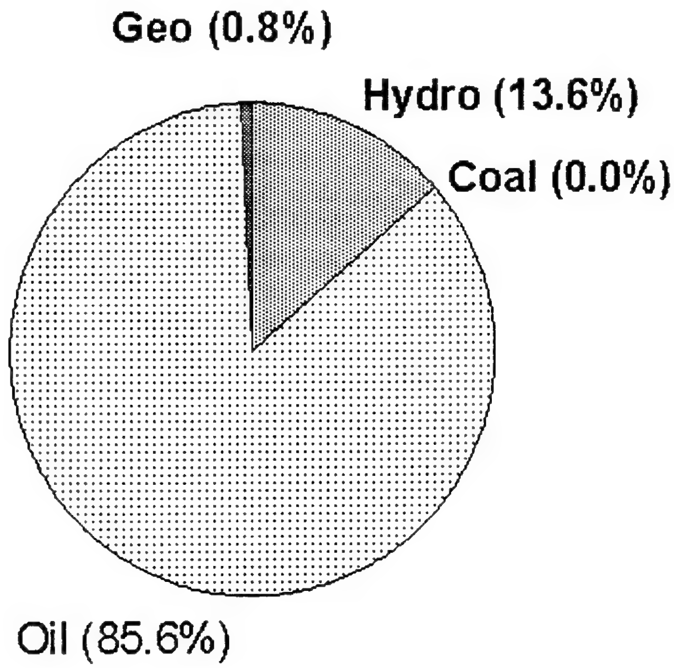

Figure 3. PLN's Installed Generating Capacity 1983/1984.
Source : National Development Information Office, 1993.

Since the last decade Indonesia has broadened its power generation base to include the use of gas, coal, hydroelectricity, and geothermal energy. Because of those technologies of electricity generation came on line, the percentage of various types of generation have changed significantly. Until 1992/1993 the oil-fired and gas types of electricity generation reduced to only 56.9 percent of the total installed capacity as shown in Figure 4.

Table 1 gives us an illustration of the development of installed capacity of electricity generation in Indonesia to the end of 1992. To meet the future demand for electricity, Indonesia plans to build nuclear power plants, to reduce dependency on oil and coal. Until the fiscal year 1993/1994, PLN's total generating capacity available was 10,302 megawatts (MW). PLN plans to build nuclear power plants with combined capacity of 2,321 MW with 1,112 kilometers transmission facilities and distribution network. The

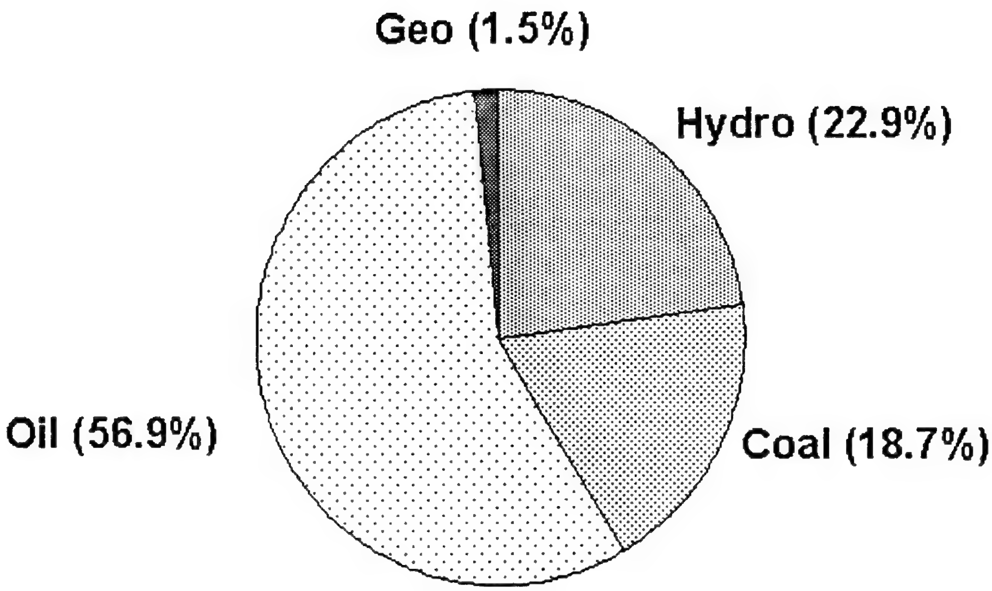

Figure 4. PLN's Installed Generating Capacity 1992/1993.
Source: National Development Information Office, 1993.

total funding required to build these new plants was estimated about U.S. $ 3.56 billion. The demand of electricity is estimated to increase by nine percent annually, and by the year 2000 the total PLN's generating capacity is projected to be 22,000 MW. By that time the privately owned generating units which are mostly used by the industrial sectors, account for about 7,500 MW of generating capacity (National Development Information Office, 1993).

Year	Total	Hydro Pwr	Steam Powered Stations Oil	Coal	Gas	Total	Diesel Pwr	Gas Pwr	Thermal Pwr
83/84	3,935	536	1,556	-	-	1,556	784	1,028	30
85/86	5,635	1,066	1,685	800	-	2,486	936	1,117	30
87/88	7,237	1,512	1,886	930	-	2,817	1,652	1,117	140
89/90	9,021	1,973	2,216	1,731	-	3,947	1,727	1,234	140
90/91	9,108	1,973	2,216	1,731	-	3,947	1,814	1,234	140
91/92	9,355	2,115	2,081	1,731	130	3,942	1,945	1,213	140

Table 1. PLN's Generating Capacity 1983 - 1992 (in MW).
Source: Puspitek-Serpong; *The Long Term Program of Electricity and the Prospect of Nuclear Power Plant in Indonesia*, July, 1992.

Those total capacities shown above are far from sufficient to meet the total demand of electricity for both industry and household throughout the country.

a. Nuclear power

Substantial research and studies on the feasibility of using nuclear power to supplement the energy needs has been conducted by Indonesia's Atomic Energy Agency (BATAN). BATAN under the auspices of the National Energy Coordinating Board. The board has been charged with the long term task of overseeing the construction of seven to twelve nuclear power generating units. The units planned capacities range from 600 to 1000 MW, and these facilities will come on line over a twelve year period. The first nuclear power plant with a capacity 600 MW reactor costs about U.S. $ one billion, and is expected to become operational in the year 2003 on Central Java. BATAN accompanied by various agencies such as State Electric Company (PLN), and foreign consultants such as NEWJEC of Japan, BECHTEL of the United States, and NIRA/ENEL of Italy have participated in the feasibility study (Puspitek-Serpong, 1992).

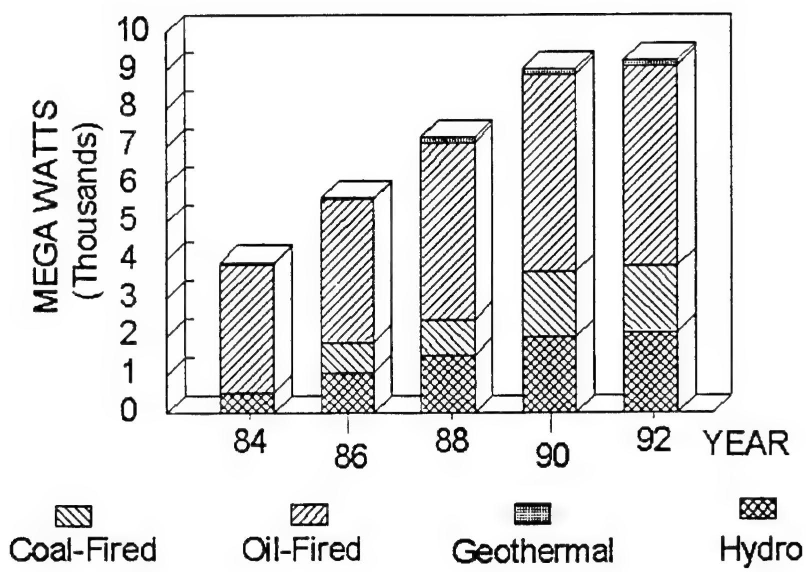

Figure 5. PLN's Generating Capacity 1983-1992(MW).
Source: Puspitek-Serpong; *The Long Term Program of Electricity and The Prospect of Nuclear Power Plant in Indonesia.*

The first site that is suitable for a nuclear power plant is on the Muria peninsula, in the northern part of central Java. Up until now the plant construction is still being competed for by different contractors who are interested in this huge investment.

b. Coal-fired Power

The coal-fired power is the fastest growing of Indonesia's energy sources. It provides 1,731 MW (17 percent) of PLN installed capacity and 25 percent of the power generated in 1993. In the year 2000 it is expected to supply 10,000 MW or about 60 percent of the total country's power, and will be concentrated primarily in Sumatra and Kalimantan Islands. The government intends to expand the use of coal briquettes to fuel 30 percent of homes and 50 percent of nation's small scale industries by year of 1998.

This will provide a significantly cheaper alternative for the household as compared to the use of fuel oil.

Several coal-fired electricity generation plants will be constructed in Java before the year 2000. Those planned projects are: four 600 MW capacity of coal-fired power plant will be built in east Java; two 600 capacity of coal-fired power plant in central Java; two 600 MW capacity of coal-fired power plants in west Java. Other coal-fired power plant projects with total capacity of 100 MW are planned to be constructed in the eastern part of Kalimantan.

The project is called the "**Piton Project**" which will be built on Eastern part of Java with total cost of U.S. $ two billion. Two combined-cycle units each 600 MW (total of 1,200 MW) by the consortium contractor of: Mission Energy BV of Netherlands (32.5 percent stake), General Electric Power Funding Corporation of United States (32.5 percent stake), Mitsui & Co. of Japan (20 percent stake) and Batu Hitam Perkasa of Indonesia (15 percent) (National Development Information Office, 1993).

c. Hydroelectric Power

Being a large archipelagic country, Indonesia has an abundance of water resource capable of generating energy. Most of the islands offer potential for the expansion of hydroelectric generating power. Throughout the Indonesian islands, hydroelectricity has accounted for 5.8 percent (in 1991). By the year 1996 it is expected to become 16.2 percent of the total country's electricity, and by the year 2000 it is projected to be 36.4 percent. The hydroelectric projects have been confined in the islands of Java, Bali, Kalimantan, Sumatra, Sulawesi and Irian Jaya.

d. Geothermal

Indonesia has implemented geothermal technology as an alternative for generating energy since 1983. Since Indonesia has a lot of mountains and volcanoes, there are about 100 of them still active, some 217 sites throughout the country are found to be theoretically capable of generating 16.035 MW of geothermal energy. Of those total generating capability, one half of it exists on Java island. Today, there are six sites of geothermal electric generating plants that have been developed throughout the islands,

ranging from 2.5 to 140 MW, with the total supply of 365.5 MW. From this total geothermal electric generating available capacity, 360 MW is produced in Java.

e. Solar Power

Solar technology is another alternative which may be developed to meet the demand of electricity, specifically in the remote islands, where there are only a few people who live on the island. At this time, the State Electric Company (PLN) has completed a solar power project with total cost of $ 1.65 million, and provides 3000 homes with solar paneled installation. By the year 2000, the government plans to extend the use of solar power generating electricity, supplying one million households on some remote islands, since this type of generating electricity is considered the cheapest way compared with extending electricity grid from Java or any other large island. A study has been conducted and calculates the cost of extending the grid of electricity beyond Java can be as high as U.S. $ 3000 per household (National Development Information Office, 1993).

2. Transportation

The geographical uniqueness of Indonesia has great influence on the transportation system used in the country. Because islands are separated by a large body of water, the air and sea transportation play the most important role to connect islands and this has a major impact on the country's economy. Land transportation plays an important role only locally and on large islands.

a. Roads

The road network is the most important means to create economic growth on local island. The better road networks has been developed on the islands of Java, Madura, Bali and Sumatra, while the rest of the islands the roads are still underdeveloped. Most cities on Java, Bali, Sumatra, Kalimantan and Sulawesi are connected by highway and secondary road.

b. Rail

The rail network has not been well-developed throughout the country. It is only found on Java, Madura and Sumatra islands. The railway system is owned by the State Rail Company, and is used extensively for freight and passenger transportation.

c. Port and Shipping

There are 349 ports and harbors throughout the country, of which 127 of them are capable of handling ocean-going ships, while the others are able to handle small vessels serving domestic or inter-island shipping. In 1990 the Indonesian fleet consisted of 35 ocean-going ships and 227 inter-island vessels with the total transport capacity was 793,000 dead-weight tons. The sea transportation is used for transporting both passenger and cargo.

d. Air Transportation

Indonesia has a total of 72 airports, six of them are capable of accommodating wide-bodied jet airplanes. The State Airline Company "Garuda Indonesian Airways" serves the international and domestic flight throughout the country. In addition to the state owned airline company, there are 25 domestic airlines, six of them offer scheduled passenger service, and the others offering charter and cargo services.

E. THE CURRENT PROBLEM OF ELECTRICITY

Indonesia is geographically unique because it is composed of thousands of islands which are separated by a large body of water, and has a large number of people. It is now developing and changing from traditional to modern life for its society, and from a small holder and traditional agriculture based to an industrial based society. The fast growing industries and services, as well as public household utilities, absolutely need a large quantity of electricity to support their activities. Unfortunately, the current available generating capacity of the nation is still far from sufficient to meet the entire demand for either public or industrial electricity. This scarcity, results in a aggregate demand for electricity that is much higher than its available supply. This condition leads to a higher

market price rate of electricity in the country compared with some other developed countries.

The amount of available electricity in the country is an important determinant of the quality of life in the modern society. The larger the capacity available, the higher the quality of life society can achieve. Until the year 1992, the per capita of electricity in Indonesia was only 260 kWh/capita (Puspitek-Serpong, 1992). This amount was far from sufficient to fulfill the standard energy requirement of modern societies. To promote the public welfare throughout the whole population including urban and rural societies, the government is willing to expand the available generating capacity by expanding the use of the various types of electricity generation. The expansion program is projected through the State Electric Company (PLN) long-term planning (Appendix A). The national budgetary constraints and the high demand for electricity become specific guides to the government's in selecting the most preferable types of electricity generation.

Budgetary constraints unfortunately limit the electricity expansion to only the basic or the most economical alternative with the least environmental damage and threat to public safety. Among the various alternatives of electricity generation, it is the most interesting to analyze whether nuclear power plants are a cost-effective method for meeting the future demand of electricity throughout the country. The big capital investment on nuclear power plants makes it difficult for the government to decide whether or not nuclear power plants are the best alternative for electricity generation in Indonesia.

III. POLITICAL ASPECTS OF NUCLEAR POWER PLANTS

A. GENERAL

The energy policy specifically dealing with nuclear power plants has become a topic of intense public concern and political debate in many countries. Such debate over various aspects of both domestic and foreign commercial nuclear policies, has existed for over two decades. The policy on the acquisition of nuclear power plants often creates conflict between neighboring countries if there are different perceptions or interests on nuclear programs. The source of conflicts can range from safety issues to the assumption that the nuclear power country will eventually embark on a nuclear weapons program, raising the neighboring countries suspicion. Some of the political issues related to nuclear policies will be discussed in this chapter.

B. ECONOMIC AND ENVIRONMENTAL ISSUES

Since the beginning of commercial nuclear industry, people thought that nuclear electricity generation had the most competitive cost compared with other electricity generation, such as coal or oil-fired electricity generation. This perception persisted until early 1970, when the United States experienced an oil embargo, which caused an increasing oil price. The operating nuclear power plants in the United States have produced the lowest cost of electricity with the average cost of U.S. $ 200 per kilo watts of generating capacity in the year 1970. The lower cost of electricity produced by the nuclear power plants result because the higher cost of constructing nuclear power plants is more then offset by the lower cost of the nuclear fuel cycle (Barrager, Judd, North, 1976; GAO Report, March 1989).

Later the nuclear power plants were viewed differently. The economic recession following the oil embargo in 1973 had created a serious impact, and changed public opinions on nuclear industry, primarily dealing with the public safety. Serious safety questions arose because of several problems that occurred at the nuclear power plants. For example, the fire damaged safety related electrical cable at the Tennessee Valley

Authority's Browns Ferry plants in 1975, and an accident at Three Mile Island in March 1979. Those accidents led the Nuclear Regulatory Commission (NRC) of the United States to set up the extensive safety regulatory applied to all plants including those under construction.

The increasing safety regulatory and design standard construction, has led to an increase in construction cost of the nuclear power plants. (GAO Report, March 1989). The increasing construction cost coupled with the economic recession and longer construction time due to design changes have resulted in the capital cost of building nuclear power plants to soar, and the nuclear electricity generation has become less economical.

Due to those facts, public opposition to the nuclear power plants in the United States grew stronger. The nuclear power opponent believed that nuclear power is not safe, and nuclear power plants represent an undue safety risk, and that they are not economical. (John, Wilson, Eric, Thor Jr, 1979; GAO Report, 1989). Their perception that nuclear power plants are not safe was confirmed with the nuclear accident at Chernobyl in 1986. This nuclear accident has strengthened and increased the number of people who oppose nuclear power in the United States.

The GAO reported in March 1989, that before the accident at Three Mile Island, over 70 percent of the United States public supported nuclear power plants as an alternative of energy generation, and only 30 percent opposed it. After the accident the number who oppose has increased to about 50 percent of the public polled. The nuclear industry and nuclear proponent argued that nuclear power is safe, because no one has ever been reported killed by radiation from commercial nuclear power plants in the United States. Nuclear power plants have very good records compared to the other industries such as chemical or coal mining. They believe that nuclear power will have an important role in meeting the energy requirement in the future. Nuclear power provides competitive cost and less environmental affects compared with coal and oil-fired power plants. Nuclear power plants have high safety risk, but the probability of an accident is very small (Barrager, Judd, North, 1976).

Studies or polls for nuclear power support have never been conducted in Indonesia, and there is no such data available representing the number of pro and con. Rather, I will refer to the data represented by the study that has been conducted in the United States or other nuclear countries, to be used as a basis for analysis whether or not nuclear power plants are a suitable choice to supplement Indonesia's energy needs.

C. URANIUM ORE AND ENRICHED URANIUM

The primary reason that some countries have developed nuclear electricity generation was to reduce their dependency on imported oil, especially after effects of the oil embargo in the United States in 1973. Increasing oil prices due to the oil embargo has motivated some countries that lack alternative of energy sources, to develop nuclear electricity generation more extensively. The nuclear fuel cycle is used as an alternative because it provides more economic benefit and less environmental damage.

In reality the use of nuclear power for energy generation to replace the dependency on oil or coal, is only viable as short-term solution, because instead of oil or coal, nuclear power plants are dependent on uranium ore, or enriched uranium and plutonium the so called fissile materials. Its dependency on fissile materials, does not replace the dependency on oil or coal (Ebinger, 1976). Therefore, a big problem still exists even more severe by using nuclear fuel cycle. The uncertainty of safety risks have become a serious public issue in many countries.

The size of uranium deposits throughout the world and its distribution, like many other mineral resources are subject of uncertainty. With an increasing number of nuclear power plants in the world, there will consequently arise a demand for uranium. The increasing demand for uranium above the available production capacity will increase the constraints on the supply uranium. As the demand of uranium increases in the world, its price will likely increase. The future cost of uranium will possibly be much higher than the predictions of its cost, hence there is no economic incentive of using nuclear fuel. Even more uranium mining is further complicated because (Ebinger, 1978):

- Uranium usually occurs in small deposits and often is associated with another mineral, hence profitability of mining is often dictated by the current market condition of the associate minerals.
- The economic attractiveness of mining marginal reserves is highly subject to price elasticities.

Those above reasons may lead to the future where uranium becomes an increasingly scarce material, and the world supply of uranium may be dominated by some countries which are endowed with large enough of uranium deposits, such as South Africa, Australia, the United States, Russia and some of the European countries. Australia is endowed with the best and cheapest uranium in the world (Ebinger, 1976). Indonesia may become dependent on Australia for its uranium supply, and the effects of this depends on the political approach between both governments. Geographically, obtaining uranium from Australia gives an advantage to Indonesia of lower cost and saving of time for transportation.

Indonesia has an abundance of natural resources which can be developed as a source of energy generation. The recent study reported by Indonesia's Atomic Energy Agency (BATAN, 1994) revealed that some uranium deposits were found on some islands in this country, such as in Sumatra and Kalimantan, but so far they have not been exploited. Uranium deposits are reported to be of only a small size. These deposits it is predicted can supply for ten to twelve years the operation of a 600 MW capacity reactor. But the ability to mine uranium and the milling of uranium are still questionable. Since the deposit is not large enough, mining and milling will not give economic benefit because the production cost of uranium may be higher than its market price.

A decision as to whether Indonesia will provide uranium fuel by purchasing from other countries or producing from its own resource should be deliberated. In the short term buying uranium fuel from another country will be more economical than producing from its own mining. But in the long term, self production will reduce dependency on other countries. Since nuclear fuel is politically controlled by an international organization in some situations due to political change, it will be difficult to buy from other countries

even though the international market of uranium indicates large supply. This condition implies that, whatever types of reactor become the choice, Indonesia will be dependent on the countries that export uranium, and the countries which have spent fuel recycling facilities. If nuclear power plants become an alternative for energy generation, and until Indonesia has its own capability of producing uranium or reprocessing spent fuel and manufactures to readily fresh fuel Indonesia will be dependent upon this country. One of the requirements for a non-nuclear country to acquire nuclear materials from the Nuclear Suppliers Group (NSG) is to sign a safeguard agreement and verify Non-nuclear Proliferation Treaty (NPT). Otherwise the non-nuclear country will not be permitted to buy any nuclear material or set up nuclear facilities.

D. SPENT FUEL

Spent fuel is produced after the fuel is cycled through the reactor. It contains radioactive products which are produced during reactor operation. Spent fuel becomes a serious concern in the management and disposal of hazardous nuclear wastes. The notions of spent fuel " as resource" and spent fuel " as wastes" makes it difficult to manage spent fuel.

In the last two decades many states have implemented nuclear technology for generating electricity. Consequently, inventories of spent fuel are also increasing rapidly worldwide, even though reprocessing plants capacity is also increasing. Table 2 shows the five leading countries in the world producing nuclear electricity generation, and Table 3 shows the reprocessing plants capability outside of non-declared nuclear weapon facilities.

Country	Number of Unit	Total Capacity (GW)
U.S.A.	112	100.6
France	56	55.7
Russia	45	39.6
Japan	41	30.9
Germany	26	24

Table 2. The Five Biggest Nuclear Countries in the World.
Source: IAEA, 1992.

The increasing quantities of spent fuel as well as the number of reprocessing plants, has the consequence of increasing inventories of plutonium. This situation makes the management of spent fuel central to both non-proliferation and wastes management negotiation. Since the spent fuel contains potential resource value of plutonium, the management of spent fuel is different from management of high-level wastes. At the end of 1990, the total nuclear electricity generation in the world was 432 units and other units were still under construction. By the end of 1995, the total nuclear electricity generation in the world will become 506 units (IAEA, 1992; Puspitek-Serpong, 1992).

Spent fuel contains both plutonium and high-level wastes. That is why finding a place for spent fuel storage is not an easy matter. Spent fuel storage facilities are required to meet standards for waste disposal with contingency and provision for the future. This means that they have to meet long-term environmental health and safety standards. It is advisable that emplacement of spent fuel be similar to one for disposal of high-level wastes. Because this preference will give a back-up for any failure in cladding or storage design.

Country	Number of Facility	Capacity (THM/yr)	Safeguards?
Japan	2	890	yes
Germany	1	35	yes
Belgium	1	30	yes
Israel	1	50 - 100	no
India	3	330	no/partly
Pakistan	2	105	NA/no
North Korea	1	pilot-scale	yes
Iraq	1 (destroyed)	lab-scale	Violation
South Africa	1	pilot-scale	yes
Argentina	1	5	partly
Brazil	1	3	yes

Table 3. Reprocessing Program and Capability Outside Nuclear Weapon States.
Source : Office of Technology Assessment U.S. Congress, 1993.

With the possibility of technical change or economic condition in the future of nuclear industry, hence retrieval of spent fuel from storage will not provide an incentive or economic benefit. Then spent fuel storage will be deemed as disposal of high-level wastes material.

E. THE SURPLUS OF PLUTONIUM

The rate of plutonium extracted from spent fuel is far exceeding the demand for Light Water Reactor (LWR) recycle or Fast Breeder Reactor (FBR) development. Despite the uncertainty in the rate of production and use, it is forecast that the accumulated surplus of plutonium separated from spent fuel will be growing steadily until the end of the century (Rochlin, 1979). The greater rate of production than demand of separated plutonium from spent fuel, will result in greater quantity of plutonium in the storage sites as well as an increase in the number of storage sites.

The quantities and number of storage sites of surplus plutonium would become serious concern and increase potential risk from non states-adversaries actions in time of political upheaval. The change in plutonium form during storage will reduce the attractiveness to diverter or thief. The best form for plutonium storage would be as mixed-oxide. Massive spiking also reduce the risks, although spiking to higher percentage makes it richer than spent fuel. The regulations requires that surplus plutonium for which there is no immediate demand for fuel, or research material are that it should be stored for the customer by a reprocessor, and to be returned only under contract or agreement between both parties.

Two forms in which surplus plutonium could be stockpiled are :

- First, the plutonium extracted from spent fuel, but not recycled for immediate re-use in reactor.
- Second, plutonium will be stored as unprocessed spent fuel.

The first option plutonium may be stored in many forms from metal to liquid nitrate solution, depend on the assumption about future material use. The preferable form would be as mixed-oxide master blend of five to ten percent plutonium concentration. While the second option will cause the spent fuel inventories to continue to grow and they could not be reduced to zero, even with the most favorable combination of reprocessing capacity and reactor installation.

Considering those two above conditions, recoverable large-scale storage of spent fuel will be necessary whether or not reprocessing and recycling are pursued by all or some nuclear countries. Common sense is that "the existence of reprocessing plants is also the existence of surplus plutonium" which later creates a big issue in the spent fuel management. The deferral of spent fuel reprocessing is deemed the one possibility of reducing the risk of plutonium theft, because the spent fuel is a hazardous material and the plutonium is less accessible than if it were separated and stored as mixed-oxide or in pure form (Rochlin, 1979). This reason makes it possible for some nuclear countries to expand their spent fuel storage capacity at reactor sites or to develop storage away from reactor facility.

Plutonium storage will always present serious political problems. Almost every nuclear industry is able to meet the technical, geological, and economic criteria for plutonium storage. But public acceptance from host states is usually difficult to obtain. The problem of siting plutonium is centered primarily on satisfaction of criteria for political stability, reliability, and security as well as acceptance of the neighbors of the host states and host state potential rivals. These conditions may create a conflict between neighboring states with different perceptions on the value of nuclear material risks. The centralized storage would probably provide physical security advantage, although it will create another risk and extra cost for transportation from the storage site to the customer or state of origin and vice versa.

F. PLUTONIUM DIVERSION

The basic principle of nuclear power is splitting an atom of uranium in the process of fission, changing the physical characteristic of atom, and releases a large amount of energy. In nature uranium occurs in two forms or isotopes, those are: Uranium 238 which is the most common of natural uranium form that consists of 99.3 percent; and Uranium 235 which consists only about 0.7 percent. An atom of Uranium 235 can easily be split to directly produce energy. The atom of Uranium 238 however, has different characteristics from uranium 235. When a neutron hits an atomic particle of Uranium 238,

it will be absorbed, then Uranium 238 changes to Plutonium 239. If Plutonium 239 is struck by another neutron, it will undergo a fission process like an atom of Uranium 235. Those isotopes Uranium 235 and Plutonium 239, are called fissile materials since they can be split directly to produce energy.

Two types of reactors which utilize different kinds of uranium have been developed, those are:

- CANDU reactor (Heavy water reactor) which is developed by Canada, utilizing non enriched or natural uranium 235.
- Light Water Reactor (LWR), developed by the United States which use uranium 235 that has been enriched to three to four percent.

Those two different technologies give advantages one over the other, depending on the size of reactor will be operated. Table 4 shows the advantage and disadvantage for CANDU and LWR reactors.

	CANDU	LWR
Advantage	Does not need enriched uranium for fuel, so CANDU reactor may have lower cost for fuel.	Can use plutonium 239 produced from recycling spent fuel, means reduce the cost of fresh uranium.
Disadvantage	Produces more plutonium that may rise the problem of management of spent fuel.	Need uranium enrichment for fuel, that may increase the cost of fuel.

Table 4.The Advantage and Disadvantage of CANDU and LWR.

The availability of budget and other resources will probably become the most important consideration on selecting the type of reactor. The better idea is to have mixed type of reactors CANDU and LWR, since the spent fuel produced from CANDU may be reprocessed and used for LWR, which in turn may reduce dependency on the supply of uranium. Although reprocessing of spent fuel itself is not an economical way of producing nuclear fuel.

Since the beginning of nuclear era, people have recognized some potential problems dealing with uranium-plutonium fuel cycle. People thought that the link between development of commercial nuclear power and nuclear weapon would become controversial and political issue, because :

- Any enrichment plant is theoretically capable of enriching uranium to the degree 90 to 93 percent, suitable to the manufacture of nuclear weapon (Ebinger, 1978).
- More plutonium 239 is produced in heavy water reactor(CANDU Reactor) than it does in Light Water Reactor (LWR).
- Management of spent fuel before and during reprocessing cycle is complicated, because the plutonium possesses severe health and environmental problems, and potential danger of manufacturing nuclear weapon.

The fissile material can be acquired in three ways; theft, purchase or the diversion from commercial nuclear plant. Each of these options are illegal and prohibited to NPT non-nuclear-weapon states and to states that are parties to nuclear-free zone treaty (Office of Technology Assessment US Congress, 1993). Therefore plutonium storage in the case where it is not directly reprocessed and immediate use as fuel is another major problem. It must be stored and securely protected to avoid the theft or clandestine diversion by government, political terrorist and other criminal activities. Lack of security and protection may result in a plutonium black market as has been indicated recently occured in Germany, (Washington Post, 17 August 1994). An alleged example of clandestine diversion of plutonium is the Indian detonation in 1974 (Ebinger, 1978).

Nuclear energy for electricity generation has widely spread to many countries who lack of other energy resources, such as water, coal or oil. However, nuclear electricity generation requires large quantities of plutonium, natural uranium ore, or enriched uranium used as fuel. Those fissile materials have potential danger for making nuclear explosives, and of radioactive contamination. Even more the explosion of illegally made nuclear weapon has a greater threat and is more harmful to the public than any plausible nuclear power plant accident, that includes one involving a core meltdown and subsequent breach of its containment (Rosenbaum, Barrager, Judd, North, 1976).

Indonesia is one of the IAEA membership, and has signed the Non-nuclear Proliferation Treaty, and ASEAN regional treaty ZOPFAN. Consequently, it will not embark on the nuclear weapon program. The potential risk of plutonium diversion, or theft from having nuclear power plants should be carefully deliberated.

G. NUCLEAR SAFEGUARD

Commercial nuclear power plants have potential problems of plutonium diversion, theft, and other political terrorist or criminal activities. To prevent a nuclear power plant from becoming a source of danger such as manufacturing of crude nuclear weapons, the international control of nuclear power plants is needed. Three international organizations have been set up to deal with nuclear energy around the world, they are: the International Atomic Energy Agency (IAEA); the Nuclear Energy Agency (NEA); and the European Atomic Energy Community (Euratom). Those three international organizations have cooperated very well in dealing with nuclear energy among membership countries so far as they are viewed to have redundancies of capabilities and roles and some conflict in their purposes (Rochlin, 1979).

The International Atomic Energy Agency (IAEA) is the only one that has a global scope, being a member of United Nations Organization, while the others have only dealt with regional problems. Another agency is the International Energy Agency (IEA), which also involves only nuclear power and oversees and coordinates the energy policy for its membership countries.

1. The International Atomic Energy Agency (IAEA)

As its initial conception, the International Atomic Energy Agency (IAEA) was to act as a controller of all commercial fissionable materials. Its primary roles is to act as depository and allocator, monitor all production, shipment and storage and also provides safeguard against diversion and theft (Office of Technology Assessment U.S. Congress, 1993). Those tasks were considered too large array of function, and over the years the management and operation roles of the International Atomic Energy Agency were reduced to subsequent negotiation with individual state members to establish an agency, for the verification and other safeguard functions associated with NPT. Its function then served as a promoter and disseminator of peaceful nuclear technology, and gather certain nuclear data to perform research and development.

As stated in the objective of International Atomic Energy Agency safeguard in INFCIRC/53, article 28 and 29, the primary purpose of nuclear safeguard is to detect diversion or theft, with the measure is the accountancy to the level of "significant quantities" of fissionable materials, as defined by IAEA as eight kilo grams of plutonium or twenty five kilo grams of highly enriched uranium (Office of Technology Assessment U.S. Congress, 1993). If this agency detects probable of nuclear diversion in any country who possesses commercial nuclear power plants, the evidence will be reported to the Board of Governor (made up representatives from member countries) who then could report to the United Nations Security Council. The United Nations Security Council will then disclose or take an unspecific action to whom detected to diverse nuclear power plant.

The improvement of safeguarding technique and method by using modern facilities, has increased the effectiveness of IAEA safeguard. So far, there is no nuclear facility under full-time IAEA safeguards has be found to have produced fissile materials used for nuclear weapons, because the IAEA safeguard is designed to make it difficult to divert any significant quantity of fissile materials (Office of Technology Assessment U.S. Congress, 1993). So, the diversion of fissile materials to a weapons program is not an

easy or efficient operation. If something is not right, IAEA has the power to perform special inspection at declared or undeclared facilities should it find to do so.

In some countries which are not under IAEA safeguards, or have violated the safeguard agreements, production of weapons using fissile materials may have been detected (Office of Technology Assessment U.S. Congress, 1993).

2. The NEA and IEA

On the first of February 1958 the Organization for Economic Co-Operation and Development (OECD) was formed, and its name was later changed to simply Nuclear Energy Agency (NEA) in 1972, when Japan became a member. Originally its functions included the promotion of technology, interchange specialist and data, studies of reactor characteristic and other service roles. It now operates primarily as a forum of activity coordination of its members. Its role in safeguarding has never been implemented (Rochlin, 1979). Since 1976, most of the Nuclear Energy Agency effort was directed towards investigation of safety and regulatory matters including the management of radioactive wastes.

The International Energy Agency (IEA) was established in 1974, primarily in response to the oil embargo during this period. Its membership was subset of the OECD members and in addition France. The role of the International Energy Agency in nuclear fuel cycle is comparatively small, since its primary mission was to deal with oil energy. It cooperates with the Nuclear Energy Agency to conduct survey of the world uranium resource and nuclear energy research and development.

3. Technical Strategy to Improve Security of Nuclear Fuel

The spent fuel has potential risks of theft and diversion, because it contains plutonium and high-level radioactive wastes. A clandestine or secret facilities required to extract purely plutonium chemically sufficient to fabricate crude nuclear weapon is a likely possibility. In order to reduce the potential risks of theft and diversion of plutonium, some technical aspects to improve security are required.

There are three different approaches rendering the materials more difficult to steal or divert and increasing physical security of separation of spent fuel chemically, these are:

- Denaturing, to render the plutonium useless for weapon purpose
- Spiking with radioactive isotope to make it more difficult to handle
- Dilution with 'inert' material to make theft or diversion more difficult or more detectable.

These technical procedures may be complicated by the increase plutonium production that is not immediately used, and potential for diversion or theft detection.

H. TRANSPORTATION OF NUCLEAR FUEL CYCLE

Transportation of nuclear fuel cycle has also become an important issue in dealing with nuclear power plants, because fuel fabrication, spent fuel reprocessing, and the reactor plants are all at different sites. In order to provide security assurance, any movement of nuclear fuel must be done by qualified personnel using special equipments and containers designed to convey radioactive materials. Anyone who is involved in handling of radioactive material must comply with the regulation. This is important because in case of an accident or any escape of material may result in unacceptable high-level contamination to the environment.

Transportation of nuclear material has potential risk from attacking by non-states-adversaries. For this reason, some possible technical strategies to secure nuclear materials in transit against various threats is needed. Such strategies are; modification of materials form; increase the physical difficulty to obtain or opening the shipping container; and the shipment in massive casks so that special equipment is needed to remove them from the vehicle.

The regulation of handling radioactive materials needs to be set up uniformly, to facilitate the free movement of nuclear material package in any country, and provide

protection during international transit. The protection of nuclear fuel and material of nuclear fuel cycle during international transit must be under safeguard of International Atomic Energy Agency (IAEA) as specified below:

> 91. The agreement should provide that nuclear material subject or required to be subject to safeguards thereunder which is transferred internationally shall, for purposes of the agreement, be regarded as the responsibility of the states:
>
> a. In the case of import, from the time that such responsibility ceases to lie with the exporting state, and no later than the time at which the nuclear material reaches its destination; and
>
> b. In case of export, up to the time at which the recipient State assumes such responsibility, and no later than the time at which the nuclear material reaches its destination.
>
> The agreement should provide that the states concerned shall make arrangements to determine the point at which the transfer of responsibility will take place. No State shall be deemed to have such responsibility for nuclear material merely by reason of the fact that the nuclear material is in transit on or over its territory or territorial waters, or that it is being transferred under its flag or in its aircraft.

The uniqueness of Indonesia's geography will increase the security concern for nuclear transportation to the various islands. In case of transporting nuclear fuel from the fabrication plant to the electricity generation plants, it must be safeguarded or escorted by military ship to protect it from terrorist or piracy. The crews who are carrying nuclear fuel should be equipped with special arms to protect themselves from criminal activities. The nuclear container must also be secured and assure the safety standard, in case the nuclear container becomes lost at sea due to piracy or action by terrorist, it will not cause unacceptable environmental risk.

So far, there is no case of reported piracy in Indonesia's territory (interview with CDR. Supit, ex staff of Navy Headquarter), since Indonesia does not have any nuclear power plants in operation. But, in the future piracy must be anticipated if and when Indonesia fully embarks on a nuclear power program and is involved in nuclear shipment

activities. It may be a better idea to ship the nuclear material through various islands using military transportation, to assure security.

IV. THE ECONOMIC COST ASSOCIATED WITH NUCLEAR FUEL CYCLE

A. GENERAL

Beginning in the year 1973 when the United States experienced an oil embargo, the trend has been to increase nuclear electricity generation, due to the increased price of oil in the world. Several years later it was estimated that by the end of the century, nuclear electricity generation would contribute about one third of electricity generation in the world (BATAN, 1979). The increased oil price caused nuclear electricity generation production to become the most economical electricity generation method during this period. Nuclear generation offers several advantages over other types of electricity generation, such as less environmental effect and low fuel cycle cost. However, the capital cost of building nuclear power plants is perceived to be higher than conventional power plants.

As pointed out in Chapter III, increasing safety requirements and design standards have had serious impacts on the capital cost of building a nuclear power plant. Design standard changes have induced higher cost of nuclear equipments and longer construction time which have resulted in the soaring capital cost of nuclear power plant construction. In this chapter I will investigate the economic cost of nuclear electricity generation as a whole by considering four different kinds of cost: capital investment, operation and maintenance, fuel cycle cost, and decommissioning.

The method used for cost calculation of the nuclear power plant is constant money to levelised cost (see glossary), because this method is appropriate for economic comparison of different types of generating plants performing similar functions such as base load electricity supply. This method also provides a basis for inter-fuel comparison and is the best basis for international comparison of plant operating under equivalent conditions. The discounted levelised cost is defined as (OECD, 1986):

> the average cost in constant money term per unit of electricity fed into the grid which, given the total lifetime output of the plant, is exactly equivalent to the capital cost of the plant including interest charges, its operating cost plus the cost of management and ultimate decommissioning.

This analysis focusses on the PWR, PHWR, and coal-fired plants and also gas-fired as an option which are assumed to be in commission in the year 2000. The economic life for a reactor is taken to be 30 years. Most countries expect their reactors to remain in service for at least this period. The lifetime load factor for all nuclear, coal-fired and gas-fired power plants is taken to be about 73 percent, even though in some cases the load factor may be higher. Seventy-three percent will be used since the load factor is determined by demand and generation system considerations, rather than by availability. The standard currency unit normally used in the calculation is the U.S. mill (0.001$). A ten percent real discount rate per annum is used in the calculations. Most of the OECD countries have adopted this value in practice. (see the basic estimates for cost calculation in Appendix D).

B. THE COST OF GENERATION

The overall generation costs include the capital cost, operation and maintenance cost, and fuel-cycle cost, which then spread into the levelised cost by dividing it with total output at 75 percent of generating capacity. The cost then will come up with the standard unit (U.S.$) per kWh electricity. Each of these types will be discussed below.

1. Capital Cost

The capital cost can be regarded as the total investment of the nuclear power plant. It is composed of various elements of cost; direct cost, indirect cost, contingency cost, common facility cost, and allowance for fund during construction. The estimate of direct cost can be further broken down into several categories:

- Land and land rights.
- Structure and development.

- Reactor plant equipments.
- Turbine generator unit.
- Accessories electric equipment.
- Miscellaneous power plant equipment.

It may be expected that some countries would have a different figure of anticipated capital cost, depending on how the country accommodates the various cost factors influencing the capital cost. These are: contractual arrangement; design differences due to difference requirement; difference in employing factor costs (labor, materials, energy); contingency allowances incorporated into the base capital cost estimates; and the anticipated construction period. The contingency cost is a fund necessary as a response to purely engineering uncertainty, dealing with the interaction of engineering practice and safety regulations.

The different ways contractors arrange their contracts will result in differences in the total cost. The discount rate used by the contractor with different estimates of construction period, and other matters included in the contract, will result in different capital cost. Another factor affecting total cost is the requirement of the customer to meet safety standards due to differences in conditions or location that require different designs. For examples, the method of cooling, desulphurization, will result in different total costs. Also, the manufacturing and construction experience of a series of productions and replications may reduce labor and common service cost, and hence reduce the total capital cost.

The OECD study of the cost of nuclear electricity generation showed many experiences in various countries. For example, in France the combined effects of scale, replication, and optimal erection of schedule could have saved as much as 12 percent of the capital cost. In Canada setting up a multiple unit site provided a benefit of as much as 30 percent less of the capital cost. The U.K. might have reduced the capital cost about 30 percent by reducing construction time, and eliminating the introductory and tooling cost to support contingencies. (OEDC Report, 1986)

The OECD study reported in 1992 that the base construction cost of nuclear power plants with ten percent discount rate at 1991 U.S. dollar value, ranges from U.S. $ mill 15.9 /kWh (in CSFR) to $ mill 45.4 / kWh (in the U.K.) while in other countries ranges from U.S. $ mill 23.7 / kWh to $ mill 28.5 /kWh. Table 5 shows the selected comparative investment cost of nuclear power plants in the world. The base construction cost of coal-fired plant ranges from U.S. $ mill 12.09 /kWh (in China) to $ 30.56 /kWh (in Japan). For the other OECD countries projected the cost of coal-fired generation at U.S. $ mill 15.8 /kWh to $ mill 23.73 /kWh.

Country	Reactor Type	Base Construction	Contingency	Interest	Decommission	Others	Total
Canada	PHWR	28.2	0(a)	13.5	0.015	3.0	44.7
France	PWR	18.7	0.82	6.0	0.079	0.69	26.2
Germany	PWR	37.9	0(b)	12.6	0(c)	3.51	54.06
Japan	LWR	34.08	0	12.3	0.09	0	46.5
U.K.	PWR	45.4	0	18.6	0.49	0	64.53
U.S.A.	ELWR	20.7	4.1	11.1	0.79	2.86	39.56
China	PWR	17.0	1.9	10.52	0.17	0	29.57
CSFR	PWR	15.19	0	8.38	0.16	0	23.7
India	PHWR	19.76	1.0	11.8	0.031	0	32.6
Korea	PWR	23.65	2.17	11.8	0(c)	0	37.6

Notes: Selected comparative investment cost of nuclear power plants in the world for projected plant operation in the year 2000, at 10 percent discount calculated in dollar value 1991.

(a) Included in Base Construction Cost Contingency is 15 percent of original base construction cost.

(b) Included in Base Construction Cost

(c) Included in O & M Cost

Costs are in US $ mill/kWh.

Table 5. Comparative Investment Cost of Nuclear Power in the Year 2000 (in US $ mill/kWh).

Source: OECD Report, *Projected Cost of Generating Electricity*, 1992

In the case of nuclear power plant the United Kingdom placed the highest cost in the world for the base cost of constructing a nuclear power plant. Japan placed the highest cost for the base cost of constructing a coal-fired plant. While Germany reported the lowest base construction cost for nuclear power plant and China reported the lowest rank of base construction of coal-fired power plant. Table 6 shows us the selected comparison of coal-fired power plant investment cost in the world.

Country	Type	Base Construction	Contingency	Interest	Others	Total
Canada	PCC/WLS	18.46	0(a)	3.78	2.37	24.6
France	AFBC/ESP	16.21	0.768	3.46	0.32	20.75
Germany	PCC/ESP	23.65	0(b)	4.09	0.98	28.73
Japan	PCC/FGD	30.56	0	7.6	0	38.16
U.K.	PCC/ESP	28.84	0	3.57	0	32.4
U.S.A.	PCC/ESP	18.01	2.81	9,41	1.74	32.68
China	PWR	12.89	1.44	5.0	-	19.33
CSFR	PWR	17.46	0	4.54	0	22.0
India	PHWR	16.0	0.8	6.28	0	23.1
Korea	PWR	14.27	1.42	3.56	0	19.25

Notes: Selected comparative investment cost of coal power plants in the world for projected plant operation in the year 2000, at 10 percent discount calculated in dollar value 1991.

(a) Included in Base Construction Cost Contingency is seven percent of original base construction cost.

(b) Included in Base Construction Cost at 10 percent of the original base construction cost.

(c) Included in O & M Cost

Costs are in US $ mill/kWh.

Table 6. Comparative Investment Cost of Coal-fired Power in the Year 2000 (in US $ mill/kWh).

Source: OECD *Report, Projected Cost of Generating Electricity*, 1992

For comparison we may look at another alternative of the base construction cost of gas-fired power plant. The OECD reported the world cost of gas-fired construction projected operation in year 2000, ranges between U.S. $ 6.32 /kWh to $ 19.45 /kWh. While in most countries projected the cost of gas-fired construction as much as U.S. $ 8.7 /kWh to $ 12.65 /kWh.

2. Operation and Maintenance Cost

The operation and maintenance cost for both nuclear and coal-fired electricity generations are comparable. The operation & maintenance cost for both nuclear and coal-fired electricity generation are largely fixed and independent from the plant load factor. This means that the cost of operation and maintenance of the plant is not dependent on the output of electricity produced by the plant, but it is dependent on the operating hours for continuous operation of the plants.

According to the OECD study reported in 1992, the operation and maintenance cost for the LWRs ranges from U.S. $ mill 5.4/kWh (in Canada) to $ mill 16.4/kWh (in U.S.A.), at plant capacity 75 percent load factor. In some countries such as India and Korea include the heavy water and back-end fuel costs in the operation and maintenance cost (Table 7).

The operation and maintenance costs of coal-fired power plants are lower than nuclear plant operation costs. It ranges from U.S. $ mill 4.0/kWh (in Canada) to $ mill 15/kWh (in Germany), at load factor 75 percent (Table 7). While the gas-fired power plants incur the lowest operation and maintenance cost among types of electricity generation, it is reported that the world operation and maintenance cost of gas-fired power plants as much as U.S. $ mill 2.8/kWh (in CSFR) to $ mill 7/kWh at the same capacity 75 percent load factor (OECD, 1992).

The operation and maintenance cost differences in many countries are dependent upon the scale of the utilities operation, design of the reactors, and the regulations also effect the cost. The bigger scale of utilities in co-location or a multi-unit site may reduce the operation and maintenance cost to as much as one third that of a single reactor due

to reduction in inventory of spares and smaller labor force needed per kWh, such is the experience of the Canadians (OECD, 1986).

Country	O&M Nuclear US $ mill/kWh	O&M Coal-fired US $ mill/kWh	O&M Gas-fired US $ mill/kWh
Canada	5.4	4.0	3.1
France	9.6	9.1	5.4
Germany	13.1	15.0	-
Japan	11.1	8.0	7.0
U.K.	11.3	12.9	6.5
U.S.A.	16.4	10.2	2.5
China	6.7	5.3	-
CFSR	7.4	7.5	2.8
India	12.0	4.2	-
Korea	11.9	8.9	-
Indonesia	Not Specified	Not Specified	Not Specified
Average	10.49	8.50	4.55

Table 7. Operation/Maintenance Cost of Nuclear, Coal, Gas Power Plants.
Source: OECD Report, *The Projected Cost of Generating Electricity*, 1992.

When dealing with nuclear electricity generation, the operation and maintenance cost varies with the schedule adopted for refueling, and the reactor types and design. For coal-fired electricity generation, operation and maintenance cost depends on the adoption of desulphurization and denitrification technologies. If these technologies are adopted, it may increase the operation and maintenance cost.

The number of people employed in the plants is also a factor in the operation and maintenance cost variations. In some countries the number of employees for nuclear electricity generation with 1,000 MW capacity, varies between 200 to 555, and for 2 X 1,000 MW capacity will be as many as 400 to 559 employees. In contrast, a coal-fired power plant with capacities of 500 to 600 MW, needs as many as 100 to 200 employees.

Therefore, operating at a bigger scale of capacity with a multi-unit site, and adjusting the number of employees for adequate operation of the plants may reduce the operation and maintenance cost.

In some cases the operation and maintenance cost may cover the mid-life refurbishment cost. In this study this refurbishment cost will not be included in the calculation of operation and maintenance cost since the calculation of projected cost of the plants are based on the base load capacity and within a 30 year economic lifetime.

The common factors included in the operation and maintenance cost calculation by most of nuclear powered countries are:

- The cost of on-site staffs and employees.
- The cost for off-site technical support.
- The fixed and variable expenses for maintenance materials and operating supplies.
- The administrative and general expenses including pension and benefit, nuclear insurance premium, and regulatory fees.

The on-site staff and employees includes the plant manager and assistance manager, and the employees performing the functions as: public relations; environmental control; quality assurance; training; engineering for safety and fire protection; administrative services; and security. The on-site operation staff members includes: supervisor; shift maintenance worker; quality control staff; and storekeeper. The on-site technical support staff perform function such as: reactor engineering; health physics; radiochemical and water chemical analysis; and technical support. The cost estimated for the on-site staff and employees is dependent on the staffing level and the wage rate. The off-site technical support includes: research and development; quality assurance and fuel design.

The maintenance materials includes expendable materials and all items that are replaced for continuing system operation. The cost of large item replacements should be

capitalized in the capital investment cost and amortized over the life of the plant. Materials included in the maintenance and operation are: supplies and expenses including consumable materials that are unrecoverable after use such as chemicals, gases, lubricants, office and personal supplies, data processing expenses, rents, and wastes management expenses.

The administrative and general expenses will include: the pension paid to the retired employees; payment for accidents, sickness, hospital and death benefits; payments for medical, educational and recreational activities; the cost of inspections, license reviews, and other applications; the cost of nuclear insurance including the cost of commercial liability insurance and self insurance; and the cost of property damage insurance and fund for clean up following a nuclear accident. In general, the cost of administrative and general expenses may account for the highest percentage of the total maintenance and operation cost. For example, in the United States, the administration and general expenses represents as much as 30 percent of the non-fuel operation and maintenance cost (OECD, 1992).

3. Nuclear Fuel Cycle Cost

Nuclear fuel cost is subject to many differences in various countries. It is dependent on the national policy and the expectation of nuclear fuel cost, and the type of reactors being operated. The CANDU reactor is perceived to have the lowest cost of nuclear fuel because it does not need enrichment of the fuel for its operation. According to: OECD report 1986, the CANDU reactor can operate with nuclear fuel as much as U.S. $ mill 4.0/kWh (1984 dollars). While the other type of reactor such as PWR, fuel costs range from U.S. $ mill 6.3 to U.S. $ mill 9.7/kWh for once-through cycle, and U.S. $ mill 7.1 to U.S. $ mill 10.4/kWh for reprocessing cycle. This data shows that the reprocessing cycle will incur a higher cost of fuel than does a once-through cycle fuel approach.

Therefore, the decision on the fuel cost expectation and policy is important in determining the cost of nuclear electricity generation. For example, the U.S. and Canada

used the fuel cycle cost based on the once-through cycle fuel, while French, U.K., Japan and other countries used fuel cycle cost based on the reprocessing cycle.

Factors that will generally be included in fuel cycle cost calculation are:

- Mining and milling
- Conversion
- Enrichment
- Fuel fabrication
- Fuel transportation (includes transportation prior to fuel fabrication, spent fuel and high level wastes).
- Fuel inventory carrying charge
- Spent fuel reprocessing
- High level wastes disposal

Each factor above incurs different costs, and the total of fuel cycle cost will represent the sum of these factors.

4. Coal and Gas Prices

To provide economic comparison between nuclear, coal-fired and gas-fired types of electricity generation, one needs to consider the cost of coal and gas used as a fuel. The world coal price varies from country to another, dependent upon the availability and quality of the coal. The cost of coal to the user is much influenced by the proximity and transport requirement to the plant sites. The cost of coal in the world is projected in the year 2000 measured at dollar value in 1991 at ten percent discounted rate with escalation 0.7 percent per annum, to range between U.S. $ mill 12.5/kWh (in CSFR) to $ mill 49.3/kWh (in Germany). While the gas price is projected at U.S.$ 30.6/kWh (in U.K.) to $ mill 51.4/kWh (in Japan) (OECD, 1992).

Indonesia is a producer of coal and also natural gas. The cost of coal in Indonesia is as much as $ 16 per tones and $ 33 per tone at the plant site, or as much as U.S. $ 1.1 per GJ measured at dollar value in 1992.(Newjec Inc. 1992)At ten percent discount an inflated of seven percent annually then in the year 2000 it is estimated to be US $ mill 15.01 / kWh. While the gas price can be estimated at the average world price for OECD countries that price is expected to be US $ mill 38.6 kWh in the year 2000. (Table 8)

Country	Nuclear US $ mill/kWh	Coal-fired US $ mill/kWh	Gas-fired US $ mill/kWh
Canada	1.8	15.6	40.7
France	9.3	28.9	42.9
Germany	10.0	49.3	-
Japan	17.1	33.4	51.4
U.K.	8.1	19.4	30.6
U.S.A.	5.5	17.1	40.1
China	9.9	19.2	-
CFSR	9.3	12.5	26.3
India	7.1	25.5	-
Korea	6.0	22.9	-
Indonesia	Not Specified	15.0(a)	38.6(a)
Average	8.41	23.53	38.67
Note: (a) Estimated cost			

Table 8. Comparative Fuel Cost.
Source: OECD Report, *The Projected Cost of Generating Electricity*, 1992.

5. The Cost of Overall Generation

The cost of overall nuclear, coal-fired and gas-fired electricity generation is the sum of the capital investment cost, operation and maintenance cost and the projected fuel cost along its lifetime operation. The world cost of overall nuclear electricity generation ranges from U.S. $ mil 40.4 (in CSFR) to $ mil 80.6 (in the U.K.) at ten percent discount rate calculated at 1991 dollar value. While the coal-fired electricity generation ranges from US $ mil 42.1 (in CSFR) to $ mil 93.6 (in Germany). Table 9 shows the comparative overall electricity generation in the world.

Country	Total Cost of Nuclear Generation	Total Cost of Coal-fired Generation	Total Cost of Gas-fired Generation
Canada	49.5	43.0	56.0
France	45.2	58.9	57.9
Germany	77.4	93.6	-
Japan	74.7	79.6	81.3
U.K.	80.6	66.1	46.8
U.S.A.	61.5	60.1	53.5
China	46.2	43.8	-
CFSR	40.4	42.1	40.6
India	52.9	53.1	-
Korea	51.1	51.1	-
Indonesia	Not Specified	Not Specified	Not Specified
Average	57.95	59.10	56.01

Table 9. Projected Cost of Generating Electricity (US $ mill/kWh).
Source: OEDC Report, *Projected Cost of Generation Electricity,* 1992

C. THE COST OF DECOMMISSIONING

Like any commonly used machine or industrial facility, the nuclear power plant will likely be shut down when it is not economical. In other words, the cost of keeping it in operation is greater than its benefit. As the plant gets older, some parts will become worn out and need replacement or repair. The cost needed for the part replacement to keep the plant in operation will normally go up due to increasing number of parts required to be replaced or repaired. At this stage, economic assessment of capital investment should be taken and evaluated. If the rate of return is still above a minimum threshold level, the plant may still be kept in operation, and repair or maintenance expenditure can be undertaken. If it is below the minimum threshold level, the plant will be better shut down. Examples are the nuclear electricity generation at Berkeley and Bradwell in the United Kingdom. The Nuclear Installation Inspectorate (NII) identified several safety problems which had to be resolved and rectified for the next three years of continuous operation. After the Central Electricity Generating Board (CEGB) appraised the cost of making necessary repairs at each station, and the benefits of continuing them in operation, the board decided to shut down the Berkeley Nuclear power plant, and kept the Bradwell nuclear power plant in operation (Fothergill and MacKerron, 1990).

In the United Kingdom, the average operating cost of nuclear power plants and coal-fired power plants has reached equality at 2.0 £/kWh in 1988, while in the United States was reported that the non-fuel operating cost of nuclear power plants has risen annually from US $ mill 4.07/kWh to US $ mill 4.86/kWh in 1984, in constant money 1982 (Fothergill and MacKerron, 1990).

The cost of decommissioning a nuclear power plant is divided into two distinct operations (Fothergill and MacKerron, 1990) these are: engineering work at sites which includes sealing and dismantling of facility; and the management and disposal of the wastes product.

1. Engineering Work Sites

Dealing with nuclear power plant decommissioning, political concerns sometimes involves questions of timing of the demolition. The political concerns make the technical aspects of the decommissioning more uncertain, and the uncertainty of timing of demolition further creates uncertainty of financial costs involved. There is a three-stage route for nuclear power plant decommissioning favored by many countries they are: Stage I: defuelling the reactor; Stage II: the demolition of the ancillary plant; and Stage III: the demolition of reactor and complete site clearance. These three stages may happen sequentially, but Stage III which is involved with reactor demolition may be deferred until its radioactivity decay is at acceptable levels. That will take about 100 years (OECD, 1986; Fothergill and MacKerron, 1990).

The cost estimates for nuclear power plant decommissioning are not generally the same for every nuclear plant. It varies due to the types of reactor, and also the degree of radioactive contamination. For example, the Magnox reactor and the Advanced Gas-cooled Reactor (AGR) are physically very large structure reactors that are comprised of graphite core housed in steel and concrete. While the PWR is generally smaller than those Magnox and AGR. Consequently, those Magnox and AGR cost of decommissioning is higher than PWR because of the volume of materials involved. The degree of radioactive contamination is dependent partly on the length of time that the reactor is in operation. In general, the longer the reactor is in operation, the greater the irradiation will be, but it is also dependent on other design idiosyncrasies.

The estimated cost of decommissioning nuclear power plants have varied from one type of reactor to another, and also varies with the amount of contingency allowances taken by different agencies. For examples, the U.S. experiences on the cost of nuclear power plants decommissioning estimated by Wolf Creek and Diablo Canyon on PWRs of the same size. The Wolf Creek estimate at the lower end of the current rate in the U.S. is as much as U.S. $ 140 millions or U.S. $ mill 21/kWh assuming that the decommissioned plants capacity is 1000 MWe. While the Diablo Canyon estimated for each unit is as much as U.S. $289 millions or U.S. $ mill 43/kWh, and even higher for

some U.S. reactor (Fothergill and MacKerron, 1990). These variances shown in the above examples are due to the different assumptions on the contingency allowances taken by Wolf Creek and Diablo Canyon. In general, the decommissioning cost of nuclear power plants are now estimated to be as much as twenty percent of the original cost of construction.

The amount of the contingency allowances added to the cost of nuclear power plant decommissioning for U.S. is 50 percent for Diablo Canyon, and 25 percent for Wolf Creek. The United Kingdom experiences different figures. For Magnox reactors decommissioning for Berkeley, CEGB put 50 percent for Stage II, and 75 percent for Stage III (Fothergill and MacKerron, 1990).

2. Management of Wastes Disposal

The major element of decommissioning cost is the regulatory standards which are already tightened by the safety programs. Complying with the regulatory standards will impose higher cost on the whole decommissioning program. The recent U.S. studies of management of wastes disposal showed that the cost figure of wastes disposal to be as much as U.S. $ 90 per cubic foot, in some places in the United States. The cost will likely continue to escalate. The higher the regulatory and political interest are, the more inevitable the result that cost will continue to go up (Fothergill and MacKerron, 1990). As a result, the decommissioning cost of nuclear power plants will become more uncertain in the future. For example, consider the cost of Berkeley nuclear power plant in the United Kingdom. In CEGB there were significant changes to the estimated cost of Magnox decommissioning between 1982 to 1988, especially the cost for Stage III. The expectation of more stringent on wastes disposal will substantially increase the final cost of the wastes disposal.

V. ECONOMIC BENEFIT PROVIDED TO INDONESIA

A. GENERAL

Electricity is a commodity which can be generated several ways. It can be produced from falling water or expanding steam as a result of converting heat energy from fossil fuel or radioactive isotopes. Electricity can also be generated from the earth's thermal energy, wind energy, or sun's radiation, although these sources of energy have been little utilized. After transmission from the generation site to the end user, electricity is converted into mechanical works, or other kinds of energy, which may improve the well-being of people. The amount of electricity available to the people, will determine the quality of life in a modern society.

The electricity producers like any other businessmen, who want to survive in a competitive market economy, must be able to find the cheapest way to produce the desired commodity. As in productive enterprise, the electricity producer is limited by the economic constraint. Electricity differs from other commodities in that, it cannot be stockpiled in any significant quantity. This makes electricity production, transmission, and distribution must be considered in an economic scale in order to provide the optimal benefit to the people.

In the past, people assumed that nuclear technology generated electricity would be at a lower costs than any other alternatives of electricity generation. But in fact, the unquantified risks of nuclear power generation may overwhelm the benefits. Risks such as the potential release of radioactive materials, reactor accidents, fissile materials theft and plutonium diversion. They came to this conclusion because most people recognized only the ultimate expenses of nuclear technology. They did not account for the unanticipated maintenance which may take place during the lifetime plant operation.

The factors that determine the economic success of a nuclear power plant investment are unanticipated maintenance and retro-fitting of parts, the cost of accident, radioactive and toxic release during the process and scarcity of energy such as unexpected

increase of fuel price. On the other hand, nuclear accidents will reduce the electricity supply that may lead to the economic lost to industries or other end users. By adding to the available generating capacity of at least 1000 MWe may provide the people with some economic benefit for households, industries and many other fields. This chapter discusses the economic benefits of nuclear electricity generation provided to the people.

B. SOCIOECONOMIC BENEFIT

The decision to build nuclear power plants for electricity generation in Indonesia is intended to meet the demand electricity, especially in Java, Madura and Bali islands, where more than 60 percent of population live. Electricity is needed to support the development in various fields most importantly in industrial sector. The high capital investment of building nuclear power plants is expected to provide the people throughout the country with the optimal benefit.

A study of nuclear electricity generation in Indonesia includes its effect on socio-economic benefit of nuclear power plant has been conducted by BATAN in cooperation with CESEN of Italy. The first nuclear electricity generation with capacity of 2 X 600 MWe will be built at Ujung Watu, in Muria Peninsula, north part of Central Java. It is expected that the construction of the plants will be started in 1996 and will be commissioned by the year 2003 (Carakawarta, August 1994).

This nuclear electricity generation will provide the people in the surrounding area with socio-economic benefits.

1. The Employment Impact of Nuclear Power Plant Construction

Since Indonesia has no experience in constructing nuclear power plants, it is better to use the experience of the PWR construction at Sizewell United Kingdom, who have many experiences in constructing nuclear power plants. The PWR construction at Sizewell, at its peak would require about 3,500 work-force. During the nine-years construction period the direct income injected into the local economy should rise to a peak of about 50 million Poundsterling at year five. The total income injection is expected to be about 300 million (Pasqualetti, 1991). As a result of the plant construction, the labor

market should benefit with between 1,800 and 2,460 jobs. This figure consist of 1200 to 1450 direct labors, and 580 to 1010 indirect labors. Therefore the employment is the main economic benefit of the plant construction. While another benefit of the plant construction that is stressed is the opportunity of the main contractor to work with the local contractors and other suppliers on-site.

Assuming that the nuclear power plant construction in Indonesia utilizing the same above figure of labor market as at Sizewell, the local Indonesian community will obtain the economic benefit of acquiring new job opportunities between 1,800 and 2,500 jobs. This figure consist of 1500 direct labors, and 1000 indirect labors. The magnitude of income injected into the local economy will be dependent on the skill level and wage rate.

By estimating the average wage in Indonesia is at US $12,000 a year per employee than the direct income injected into the local community is about 1500 x US $12,000 = a total of US $ 18 million. And the total income injected to the local society will be estimated at 2500 x US $ 12,000 = US $ 30 million.

2. The Employment Impact of Nuclear Power Plant Operation

It is obvious that the construction of a nuclear power plant will create new jobs. Chapter IV describes that for the operation of 1,000 MW capacity of nuclear power plant there is a requirement for only about 200 to 555 employees. Therefore as the construction of the nuclear power plant is completed and preparing for operation, a lot of people will be losing their jobs. When the construction period of nuclear power plants is over, there will be about 3,000 people losing their jobs.

On the other hand, by operating the new power plant there will be an increase of available electricity. Therefore the increase in electricity available capacity will provide other opportunities for the developing of new industries, recreational and tourist development, educational service and household utilities. The development of new industries as well as recreational and tourist development, and educational services will provide new job opportunities for the people. Though the net economic benefit of these

new jobs in industrial sector and recreational and tourist area are difficult to quantify, they are never the less easy to be recognized.

The socio-economic benefit of nuclear power plants can be summarized as :

- Raise the income of the local community and create new job opportunities for the people surrounding the site within an area 20 - 50 kilometers.
- Encourage people to remain in the area and create new jobs for about 3,500 people surrounding the plant site.
- Because of increasing available electric power, new industries will be setup and will create new job opportunities. Increases electricity per capita will lead to improve the quality of life for the people.

C. THE ECONOMIC BENEFIT OF NUCLEAR POWER PLANT SITING

Site assessment for nuclear power plant is crucial because a nuclear power plant is hazardous to the public safety. The location of nuclear power plants should meet the standard requirement and safety regulation. Most nuclear power plants are located in the coastal zones. The primary economic reason for locating nuclear power plants in the coastal areas is that, the ocean provides the a reliable supply of cooling water at a very low cost in the large quantities needed for cooling the nuclear power plant. Therefore, locating the nuclear power plant in the coastal area will maximize the reliability and minimize the cost of acquiring cooling water, by using ocean water for once-through cooling system. An alternative of once-through cooling system is to locate the nuclear power plant adjacent to the river, or main irrigation, or municipal wastes water collection, but this alternative provides a less reliable and more costly alternative to ocean water supply. In addition, the river has potential of flooding during the rainy season, and being dry during dry season, which would endanger the safety of nuclear power plants.

In the case where the nuclear power plant is constructed on a mainland site, the principle of once-through cooling system may use dry or wet cooling tower. Although this alternative will increase the capital and operation and maintenance cost relative to fossil-

fueled power plants. A dry cooling tower conserves water, but is the most expensive to construct, while the wet cooling tower although a little less expensive has negative effects on the environment (Rooney and Tennenbaum, 1976).

The once-through ocean water cooling system as a matter of fact, has negative impact to the marine life, due to the heat discharge to the ocean, and the chemicals used to clean the water may hurt or kill the marine organism. In case of accident, the radioactive materials released to the ocean can enter the marine ecological system through the food chain and become widespread which then endangers larger marine life.

D. NET ECONOMIC BENEFIT OF NUCLEAR POWER PLANT

After conducting a series feasibility study on the possibility of building nuclear electricity generation, Indonesian government has made a decision to build the first nuclear power plant. These plants will be constructed at Gunung Watu, Muria Peninsula on the northern part of Central Java. The construction of first plants with the capacity of 2 X 600 MW, will be started in 1996 while the competitive seal bidding will be held by next year (Carakawarta, August 1994). So far there is no data on the cost of nuclear construction available in Indonesia.

Up until this date, Germany and Britain have been participating in developing the Piton Project (1,200 MW coal-fired power plants in the eastern part of Java), while the United States, Japan, Germany and United Kingdom are interested in the construction of nuclear electricity generation in Indonesia.

The nuclear power plants will provide more benefits than coal-fired power plants, because nuclear power plants do not emit to the atmosphere sulphur-oxide or carbon monoxide and dusts. This implies that nuclear electricity generation reduces the social cost in terms of:

- The cost of air pollution reduction.
- The cost of health.
- The cost of research on black lung disease.

Krutilla and Cicchetti, developed the equation of calculating the net benefit of nuclear power plants as :

$$NBn = (Bn - Cn) - (Ba - Ca)$$

Where

Bn = Gross benefit from nuclear power generation.

Cn = The cost of power production in nuclear power plants.

Ba = Gross benefit from alternative source, in this case coal will be used as an alternative.

Ca = The cost of power production in alternative plants.

It is assumed that between two sources of electricity generations provide an identical service, hence it is defined that Ba = Bn. So the equation of nuclear net benefit become

$$NBn = Ca - Cn$$

or the net benefit of nuclear electricity generation is equal to the cost of producing power in alternative source minus the cost of producing power in nuclear power plants. Assuming the cost of producing nuclear electricity from nuclear power plants, taking an average of the world price presented by OECD countries reports, the economic cost and net benefit of nuclear power plants in Indonesia will be as shown in Table 10.

Therefore for 1,000 MWe capacity, the nuclear power plant will save the cost of about U.S. $ 7.59 million over the coal-fired power plants. While the nuclear over gas-fired power plants will cost U.S. $ 12.8 million more than gas-fired power plants. Therefore, the gas-fired electricity generation estimate to be the lowest cost of the three alternatives.

	Nuclear	Coal-fired	Gas-fired
Construction Cost	39.05	27.07	12.79
Operation and Maintenance Cost	10.49	8.50	4.55
Fuel Cost	8.41	23.53	38.67
Total Generating Cost	57.95	59.10	56.01
The net benefit of nuclear over coal-fired power plant is US $ mill 59.1 - US $ mill 57.95 = US $ mill 1.15/kWh.			
The net benefit of nuclear over gas-fired power plants is US $ mill 56.01 - US $ 57.95 = -US $ mill 1.94/kWh. (a)			
Note: All costs are in U.S. $ mill/kWh (a) The negative sign indicates the cost of gas-fired power plants generation is lower than nuclear power plant generation.			

Table 10. Economic Benefit of Nuclear Power Plants in Indonesia.

VI. ENVIRONMENTAL EFFECT AND SOCIAL COST OF THE NUCLEAR FUEL CYCLE

A. GENERAL

In our modern society people have become more concerned with our environment, because of its direct effect on human beings. The wastes resulting from the products of various industries has major impact on the public health and the quality of our environment. Nuclear electricity generation is perceived as having less environmental affects, but nuclear generation also has the potential risks of releasing radioactive materials into the environment. This chapter will discuss the effects of nuclear electricity generation on our environment, and also qualitatively explain its social cost that the society incurs from having nuclear power plants.

It is commonly recognized that any industrial process produces wastes. Electricity generation is a process that besides generating electricity also produces wastes. The wastes produced in this process are; gases, hot water, ashes, and dusts, and in this particular case radioactive materials. In its normal operating condition, nuclear power plants produces relatively small amounts of wastes. While coal and oil-fired types of electricity generation produce relatively large amounts of wastes. Environmentally, nuclear power plants provide several advantages over coal and oil-fired type power plants, since nuclear power plants do not emit to the atmosphere gases such as carbon dioxide, sulphur-oxide, nitrogen-oxide and do not produce ashes.

The major problem associated with a nuclear power plant is the generation and potential release of radioactive materials. The amount of radioactivity generated in the reactor is primarily a function of heat generation. In the nuclear power plant, the amount of heat generated in the reactor is controlled by the control rods inside the reactor core, hence the radioactive transmission is generally under control. However, during an emergency situation and accidental release of radioactive materials, such as during an accident, the radioactivity becomes uncontrolled. The uncontrolled release of radioactive materials is very hazardous, and devastating to the public safety. For example the nuclear

power plant accident at Chernobyl in 1986, killed about 2000 people, and its radioactive materials spread to an area of 4,000 square kilometers in only a six days period (Moh. Ridwan, 1994).

Selection of new plant sites should be made in such a way that the impact of the nuclear power plant on the environment is reduced to minimum, and remains within acceptable limits imposed by regulations. This notion implies that the nuclear power plant must be stationed as far as possible from the public, but it is also must be very close to the societies who need electricity. Although those two principles will never meet at one point, the balance between the cost of electricity generation and safety should be considered and carefully evaluated.

B. RADIOACTIVITY

Instead of gases, dusts, and ashes, nuclear power plants produces and releases radioactive materials. The radioactivity of nuclear materials is a process of nature which cannot be hampered, and there is no such way to demolish it. The radioactivity of nuclear materials will persist for a relatively long period of time. The persistence of radioactivity varies from a few seconds to thousands of years depending upon the structure of an atom formed during process reaction. For example, the high-level waste produced from separation of spent fuel at reprocessing plants may persist for thousands of years. To prevent an accident as well as routine release of radioactive materials from the reactor, it is necessary for nuclear reactor design, installation, and siting to meet all the provisions which are outlined in the safety regulations.

Water and air are part of our environment, and provide the perfect means of radioactive dissemination. So all the wastes produced as a product of nuclear electricity generation, should be carefully taken care. The low level wastes produced in the form of gas or liquid, must be properly treated and filtered before routine release to the environment. This will allow our water and air which are crucial to the human life, to be free from radioactive pollutants. The low level of solid wastes which includes the residues from treatment of gases and liquid wastes, are generally disposed in the very deep seas,

or buried in the ground. The high level activity wastes are produced from separation of plutonium at reprocessing plants in the form of liquid, are concentrated and isolated effectively in the long term storage in deep repositories. Those procedures are necessary in order to keep the environment free from the effect of nuclear wastes.

C. THERMAL DISCHARGE

There are no machines that are capable of converting energy with hundred percent efficiency. Most electricity generations which are utilizing steam power turbine, attain thermal efficiency of about 40 percent or more. So there is some waste heat which is not being used during process conversion of the energy. In nuclear power plants, part of excess heat produced in the reactor is transferred to the cooling water. Therefore only a small amount of heat is released to the environment. While in the fossil-fueled power plants, the excess heat is released to the atmosphere as flue gases.

D. CORE MELTDOWN

Core meltdown is one of the potential risks with nuclear reactors especially the Light Water design Reactor (LWR). Reactor core meltdowns may happen if the core becomes partially or wholly uncovered for some reason or because of failure of the cooling system. In case of the core is not being cooled, the fuel element temperature will increase and approach the melting point of the cladding or the uranium-dioxide itself. If the core meltdown were to take place, a substantial residual of heat as a result of a decay of fission products may reach the amount of 15 megawatts (MW), until a period of 24 hours after shutdown of 1,200 MW(e) generating capacity of LWR (Nigel, 1983).

Core meltdown usually lead to a serious accident which may breach the reactor containment. Consequently, radioactive materials will be emitted to the environment and pollute an area of thousands square kilometers, and probably cause a number of casualties. For today's designs of reactors, the probability of core meltdown is very small, because previous nuclear reactor accidents have given valuable experience to the nuclear industries and the industries have improved standard designs to meet safety requirements.

E. DECOMMISSIONING

The old design nuclear reactor (Magnox-designed reactor) and nuclear electricity generation facilities were generally designed for operation during a 25 to 35 year lifetime. To reduce the probability of risk, those nuclear reactors should be decommissioned after reaching about 30 years in operation. Decommissioning of a nuclear power plant and its facilities is a difficult task and a costly procedure, because the radioactive substances remain in the structures of the reactor and primary circuit, although it is only a small part of the facilities.

In the case of an accident in the reactor, dismantling of the facility will be more difficult. Moreover, if the accident is very serious, it may be a better decision to abandon the reactor site and take necessary precautions to prevent from spreading of radioactive materials. The most important thing is to take action to restrict the public from accessing to the area. Considering these potential risks of a nuclear power plant, site assessment regarding the various affect to the environment. Before making the decision to construct a nuclear power plant, it is crucial to provide for public safety.

Nuclear power plant decommissioning has qualitatively different implications for landscape and location strategies than any other conventional industries. Because of the nature of nuclear products materials, the site of an old nuclear power plant will likely be derelict for long period of time until its radioactivity eventually decay to the acceptable level. The old nuclear power plants site may not be converted to other landscape such as; agriculture, housing estates or any other public activities. The dereliction of the site may persist until as long as one hundred years (OECD, 1986), depending on what level of radioactivity will be acceptable. Consequently, for relatively long period of time we will be losing the value of the old plant land.

Decommissioning nuclear power plants also produces a lot of wastes, because most of the materials removed from the plants are unusable. There is no salvage value of the reactor facility. None of the reactor facilities can be recycled due to the radioactive materials remaining. Those materials are considered high-level wastes and should be treated similarly as the product of spent fuel. Beginning in 1990, some of the old design

nuclear power plants started decommissioning after about 30 years in commission. Table 11 is an example of the number of estimated decommissioned reactors and wastes from decommissioning of nuclear power plants in the United Kingdom.

Time Period	Capacity MW(e)	Number of Reactors	Cumulative	Cumulative Number of Sites Effected
- 1900	332	6	6	4
1991-2000	3,385	24	30	12
2001-2010	4,636	8	38	13
2011-2020	2,640	4	42	15
2021-2030	2,640	4	46	16
2031-2040	-	-	46	16
2041-2050	2,400	2	48	16
2051-	7,200	6?	54?	17

Table 11. Expected Decommissioned Reactors (U.K.).
Source: Pasqualetti, *Nuclear Decommissioning and Society*, 1990.

Reactor	Low Level Wastes	Intermediate Level Wastes
Magnox	20,000	8,000
AGR	12,288	8,598
PWR	12,000	1,200

Table 12. Expected Decommission Wastes by Reactor Types (UK).
Source: Pasqualetti, *Nuclear Decommissioning and Society*, 1990.

F. THE SOCIAL COST OF NUCLEAR POWER PLANT

The social cost is the sacrifice by members of society which is expressed in the money equivalent. In terms of electricity generation, this social cost encompasses the cost of environment degradation because of the wastes released from the process of electricity generation. The risk that the societies may experience, and all the cost of materials and labor needed during the process of its production.

In the process of converting heat energy to electricity, nuclear electricity generation and coal-fired electricity generation are the only method which produce a comparatively low cost of electricity. These two methods have different social costs to society, but one has an advantage over the other. As we compare between the two types of plants, we note that the social cost of coal-fired electricity generation includes:

- The environmental degradation because of air pollution as a result of the wastes produced from burning coal.
- Coal mining and transportation, and storage at the plant site before it is used.
- Accidents and health risks from emission of dusts.
- The cost of research programs on "Black Lung disease", or any other respiratory disease.

The nuclear program has made a major contribution directly to the reduction of sulphur dioxide, carbon monoxide and dusts released from the conventional thermal power plant, such as coal-fired power plant. Nuclear electricity generation does not produce those above consequences but instead it does come at potential risk of releasing radioactive materials to the environment that would more severely damage the environment.

G. THE SOCIAL COST ASSESSMENT

For an assessment of the social cost of nuclear electricity generation, coal-fired and nuclear electricity generation power plants will be compared using an increment of 1,000 MW(e) generating capacity. By adding to the available capacity within the amount

of 1,000 MW(e), the same economic benefits will be obtained. One can, therefore, compare these benefits with the total cost (economic plus social cost of the two methods of generating electricity). The model of social cost assessment is shown in Figure 6.

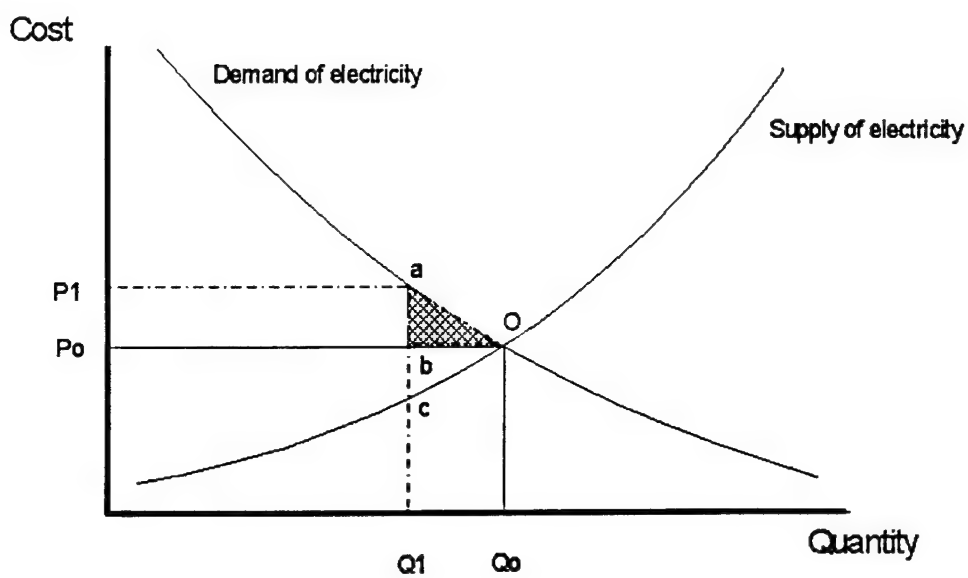

Figure 6. The Social Cost Assessment Evaluation.
Source: Barrager, Judd, North 1976; *The Economic and Social Cost of Coal and Nuclear Electric Generation.*

Assuming that Qo is the total generating capacity with new 1,000 MW(e) power plant added to the current available capacity, and Po is the market clearing price at total capacity Qo. Q1 is the total generating capacity without adding the new 1,000 MW(e) power plant, and P1 is the market clearing price at the total capacity Q1. Without adding the new capacity 1,000 MW(e), the societies will forego the amount of area triangle aOc, which is composed of two parts; the triangle abO is total foregone by the consumers, and the triangle bcO is the amount foregone by the producer (State Electric Company). By

constraining the total generating capacity available at Q1, it will also transfer the wealth from consumers to the producer, in this case from the public as a consumers to the State Electric Company, by the amount of area rectangle P1Poba. If P1-Po is the difference between prices with adding and not adding the new 1,000 MW(e) plant, than the consumers will lose the value of rectangle P1Poba, by paying higher for the quantity available Q1, or delta P x quantity Q1, by not adding new 1,000 MW(e) capacity, under the assumption that the benefit of adding new electricity power plant exceed its total cost (economic and social cost of adding the new plant).

Controlling the wastes produced from the process of electricity generation will incur a higher social cost to society. Hence it increases the total cost of electricity generation. The higher cost incurred for controlling wastes such as reducing carbon monoxide, sulphur-oxide and ashes emitted to the environment, should be lower than the cost of living with the pollution that the control eliminates. The logic is "The benefit of controlling wastes must exceed the cost of controlling them". So the benefit of having new nuclear electricity generation for 1,000 MW(e) capacity, should be higher than having coal-fired electricity generation at the same capacity plus its social cost. If the effect of controlling the wastes were distributed equally to the societies, the poor would be better off by paying more for electricity but suffering less from any disease such as respiratory ailment or black-lung.

H. THE RISK OF NUCLEAR POWER PLANT

The risks of nuclear power plants can be evaluated using the economic theory of external cost, by comparing them with the other consideration. Two salient points are noted in looking at the risk of nuclear power plants to the human health imposed by electricity generation. These are (Nigel, 1983) :

- The imposers of the risks (the actors causing the increased risks), do not in general have to pay compensation for the risks they caused.

- The risks receivers, do not in general have a choice about whether or not to accept the risks.

In the free economic market, the trade of a commodity will occur if it brings any benefit to both sides, and as a whole to society. The lack of compensation and choice means that trader does not assume the risks. So government intervention is needed to prevent the risks from continuing to increase.

According to the economic theory, any level of risks impose costs on the society, because of the death or illness amongst the risk receivers. In addition, the cost of reducing the risks is incurred by the risks imposer whatever standard of safety is introduced by the government. Figure 7 shows the model of evaluating the risks expected for having nuclear power plants.

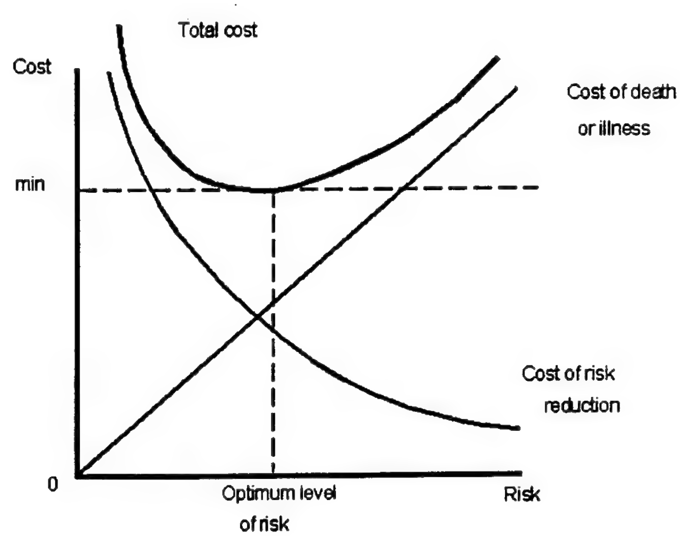

Figure 7. The Economic Risks Evaluation.

This figure shows two sets of costs, namely as the cost of death or illness caused by nuclear power plants, and the cost of risks reduction in any effort introduced by the

government agency. The level of risk that the government permits a nuclear power plant to impose is shown in horizontal axis, and the cost respectively shown in the vertical axis. The lower the level of risks required, the lower the cost due to death or illness amongst the risks receivers, but the higher the cost due to the effort of reducing the risks for society, and vice versa. The sum of both the cost of death or illness and the cost of reducing the risks is the total cost to the society. At some level of risks, the total of those two costs will be a minimum. This minimum point is the optimal level of risks to the society. Therefore, the government should design the safety standards or tax structure to achieve this point. For examples, disposal of high-level wastes buried permanently in stable geological formation in an effort to reduce the risks will cost more money, but result in less cost due to death or illness. Therefore it results in a lower level of risks to the society. Another example occurs if the nuclear industry spends more money to improve safety standard design which results in a higher cost of total nuclear power plant construction, but provides a lower level of risks and a reduction in the probability of accident, so that there is a reduction in the number of death or casualties.

VII. SUMMARY AND RECOMMENDATION

A. SUMMARY

This chapter summarizes all of the discussion of previous chapters and gives some recommendations necessary to Indonesia for its plans of building a nuclear electricity generation plant.

Indonesia is geographically unique, composed of thousands of islands which are separated by a large area of water. It is rich in natural resources, which can be used as a source of electricity generation, such as water, natural gas, oil coal as well as geothermal resources. Geographically, Indonesia has potential for natural disasters such as earthquake, tidal wave, flood, and volcano eruptions which make absolutely the need for special safety design for a nuclear reactor. This will result in higher costs for building nuclear power plants.

The population is the fourth largest in the world, and they are not evenly distributed among the islands. About 60 percent of the total population lives in Java, Madura and Bali islands which make those islands the most populous island in the world. The high population needs large quantities of electrical energy to support the daily activities. The available supply of electricity is still far from sufficient to meet the minimum requirement of the people.

The best alternatives for producing electricity will become the choice of the government in developing power plants for electricity generation. Nuclear electricity generation has become one of the choices that may be developed in Indonesia, to diversify the energy supply and to reduce dependency on any single source of energy generation. This policy will create a reliability supplying energy that can be maintained.

Nuclear electricity requires a high capital investment because it does require a high degree of safety and special design to meet the safety regulation. Because nuclear power has a potential risk of radioactive release to the environment and may endanger the public

safety requirements are stringent. The world has had two nuclear reactor disasters, at Three Mile Island in the United States in 1979 and at Chernobyl former Soviet Union in 1986. These disasters gave valuable experience to the nuclear industries, and brought new awareness of the potential risks possessed by nuclear power plants. Nuclear electricity generation is perceived to have a lower social cost, but it possesses an uncertain risk of devastating disasters, which can happen even though they have a very small probability.

The dependency on fissile materials such as uranium-235, plutonium-239 or other form of its isotopes, is not any different then the dependency on fossil fuel for coal-fired and gas-fired power plants. The amount of uranium deposit in the world is a subject of uncertainty like any other mineral deposit. Indonesia has found uranium deposit in Sumatra and Kalimantan islands which are estimated to be in very small amounts. These deposits have not been exploited. This implies that to have nuclear power plants in operation, Indonesia will be dependent upon imported nuclear fuel. Though the spent fuel can be recycled at a higher cost, the recycling process has the potential of plutonium diversion, because the plutonium-239 produced in reprocessing cycle is a basic material used to manufacture a nuclear weapon.

On the other hand, high level waste disposal and spent fuel management creates safety problem. The concept of spent fuel as "wastes" and spent fuel as "resource" also create problems in the management of the back-end of fuel cycle. These different perceptions on the spent fuel, require that the spent fuel repository meet the standards of high level waste disposal in case in a future situation change the reprocessing of spent fuel does return an economic benefit. This requires the spent fuel repository can be regarded as permanent high level wastes disposal.

The different perception and interests on nuclear power plants, may create political friction between neighboring countries. The intensity of the conflict ranges from safety issues to the suspicion that neighbors are manufacturing nuclear weapons. To resolve the problem, public acceptance of the host and neighboring countries is needed before setting up nuclear power plant facilities. Otherwise it will become a source of conflicts, or other

political activities such as sabotage, terrorist, or criminal activities organized by a group of nuclear opposition.

The cost of constructing nuclear power plant facilities varies depending on size of reactor, location, design requirement, estimated time construction, discount rate, and expected contingency allowance cost during construction and decommissioning. To reduce the cost of construction, Indonesia may expect to build multiple units at a centralized location. With the benefit of replication of design figures, shorting the period of construction and reduce unnecessary contingency allowance costs. Bigger or multiple units can be expected to reduce the common service cost, supply inventories cost, transportation cost, items production cost and interest cost.

Centralized or larger capacity units has the advantages of reducing cost and security problem, but it is also implies several disadvantages such as:

- Need for longer distribution network that raise the cost of transmission and reduce the electrical power efficiency.
- Bigger facilities safety inspection is more complex.
- If something happened in the location of the plant such as natural disaster, a larger area will lose electricity power, a larger reactor and numbers of reactors will result in a more severe nuclear disaster.

The transmission through a long grid electricity may be possible from Java to Madura, Bali islands and probably southern part of Sumatra island. While the other islands which are separated by long distance make it difficult and very costly to transmit from centralized facility generation.

Indonesia has no experience in constructing nuclear electricity power plants. The nuclear power plant project is now being studied by many agencies and nuclear industries. So far there is no data on nuclear projects pricing provided from Indonesia. In this study, we can review the data of electricity generation provided by OECD, on the projected cost of electricity generation operation in the year 2000. This data covers nuclear, coal-fired and gas-fired electricity generation in OECD membership countries. For comparison we

will take an average of the data presented by OECD countries for each type of electricity generation, which results as follows:

	Nuclear	Coal-fired	Gas-fired
Construction Investment Cost	39.05	27.07	12.79
O & M Cost	10.49	8.50	4.55
Fuel Cost	8.41	23.53	38.62
Total Generation Cost	57.95	59.10	56.01
Note: in US $ mill /kWh			

Table 13. The World Average Cost of Electricity Generation.

While this table indicates that nuclear power may be a slightly cheaper source of energy than a coal-fired plant, one has to also take account of the cost of decommissioning the nuclear power plant. In addition, the sort of economic calculations illustrated in Figure 7 must be considered. Even though the table would indicate that gas is the cheapest form of electricity production, gas-fired plants require further study. These figures, which are based on world average, may not reflect the conditions in Indonesia.

The construction of a nuclear power plant will provide job opportunities during construction period for about 3500 at the peak fifth year of construction. Direct income injected into the local society could be as much as U.S.$ 30 million (estimated value) at the peak fifth year. Total income injected is U.S. $ 250 million for the entire construction period. Plant operation requires only about 555 employees, therefore after the construction period is over 3000 employees will lose their jobs.

As people become more concerned about the environment and public safety, their assessment of the benefit between nuclear power and coal-fired power plants is crucial. If the benefit of nuclear power plants is greater than the cost of coal-fired power plant plus its social costs, then the decision to build nuclear power plants can be made.

B. RECOMMENDATIONS

After summarizing this study, my recommendations are as follows:

- Indonesia is rich in energy resources such as water, coal, gas, and geothermal that can be developed to produce electricity. Though uranium has only been detected in small deposits, Indonesia, if it develops a nation-wide nuclear power capability, should continue to explore and mine its own uranium resource in order to reduce dependency on imported uranium.

- Another way to reduce dependency on imported uranium is to mix two different types of nuclear plants CANDU reactor and LWRs. Spent fuel produced by CANDU reactor can be reprocessed and used in LWRs. Though it requires reprocessing facility, and the mixed types of reactors will result in higher capital and operating costs.

- Specially design features are required to resist earthquake and natural disaster that frequently happen in Indonesia. Java is the most populous island in the world, although the demand for electric power is greatest in Java. It is not advisable to build nuclear power plants there because nuclear power plants have potential for uncertain risks.

- The average total electricity generating cost for nuclear power plants is estimated to be U.S. $ mill 57.95/kWh, while for coal-fired power plants falls around US $ mill 59.1/kWh. Though nuclear power plants may produce somewhat lower cost of generating electricity than coal-fired power plants, the safety cost and decommissioning cost of nuclear power plants must also be considered when making determinations. The uncertainty associated with decommissioning cost indicates that further analysis is needed to better understand the magnitudes involved.

- In this analysis, the average cost of gas-fired power plants in various countries indicates that this option may have the lowest cost. Therefore, gas-fired electricity generation should be further evaluated. This may be particularly true for Indonesia because of the extent of its gas reserves.

- Nuclear materials are regulated by an international organization. If for some reason or event it becomes difficult to acquire any nuclear material or spare parts from the world market, it would be difficult for Indonesia to refuel and maintain its power plants. An even greater problem is that nuclear power plants have the potential of diversion and theft of plutonium for the making of crude nuclear weapons. Therefore, the use of nuclear power plants for electricity generation needs to be carefully evaluated both economically and politically, since Indonesia has a tradition of non-alignment in world politics.

APPENDIX A. STATE ELECTRIC COMPANY (PLN) EXPANSION PROGRAM ON ELECTRIC GENERATION SYSTEM

Type of Generator	1993/1994	1998/1999	2003/2004	2008/2009
Hydro Powered	2,046	3,150	3,150	5,789
Geothermal	250	360	360	360
Coal Powered (Steam)	2,000	8,600	20,000	22,400
Oil Powered (Steam)	1,900	1,700	1,700	731
Oil Powered (Diesel)	92	62	29	6
Gas Powered (Steam)	787	643	2,023	3,184
Combined Cycle	2,462	4,428	4,428	4,428
Total	9,537	18,763	31,690	36,898
Note: In MW				

Table 14. PLN Expansion on Java-Bali Islands.

Source: Puspitek, Serpong, *Long Term Program of Electricity and The Prospect of Nuclear Power Plant in Indonesia*, July 1992.

Type of Generator	1993/1994	1998/1999	2003/2004	2008/2009
Hydro Powered	311	1,807	3,213	4,221
Geothermal	23	248	266	540
Coal Powered (Steam)	195	673	996	9,429
Oil Powered (Steam)	310	260	260	260
Oil Powered (Diesel)	1,824	2,021	2,115	2,247
Gas Powered (Steam)	384	399	469	1,001
Combined Cycle	446	859	892	2,164
Total	3,493	6,267	8,211	19,862
Note: In MW				

Table 15. PLN Expansion Outside Java-Bali Islands.

Source: Puspitek, Serpong, *Long Term Program of Electricity and The Prospect of Nuclear Power Plant in Indonesia*, July 1992.

APPENDIX B. LIST OF ABBREVIATION AND GLOSSARY OF TERMS

Back-end (of the Fuel Cycle)

Those nuclear fuel cycle processes and activities concerned with the treatment of spent fuel discharged from reactors.

Base

The minimum load produced by an electricity network over a given period. A station used for a base load is a station that is normally operated to provide power continuously to meet the minimum load demand.

BWR

Boiling-Water Reactor.

BATAN

Badan Tenaga Atom National (National Atomic Energy Agency of Indonesia).

CANDU

Canadian Deuterium Uranium Reactor; a type of pressurized heavy water reactor.

Decommissioning

The work required for the planned permanent retirement of a plant from active service.

Denitrification

The actions taken to reduce nitrogen oxides in the exhaust gases from facilities using fossil fuel.

Desulfurization

The actions taken to reduce sulphur dioxide in the exhaust gases from facilities using fossil fuel.

Discounting Rate

Discounting is procedure to convert the value of money earned or spent in the future to a present value. If one has \$ A and it could be invested to earn interest at real money rate "r" per annum, in "t" years it would increase to become \$ $A(1+r)^t$. A sum of \$ B earned or spent in t years time can be said to have a present value of \$ $B/(1+r)^t$. The "r" is entitled a "discount rate".

ELWR

Evolutionary Light-Water Reactor.

Enrichment

Any process by which the content of specified isotope (uranium-235, etc.) in an element is increased.

Fossil-fuel

A term applied to coal, oil and natural gas.

Front-end (of the Fuel Cycle)

Those nuclear fuel cycle process and activities concerned with the production of fuel for reactor.

Fuel cycle

The sequence of processing, manufacturing, and transportation steps involved in producing fuel for a reactors, and in processing fuel discharged from the reactor. The uranium fuel cycle includes uranium mining and milling, conversion to uranium hexafluoride (UF_6), isotopic enrichment, fuel fabrication, reprocessing, recycling to recovered fissile isotopes, and disposal of radioactive wastes.

GJ

1 Giga Joule equals 1,000 million joules, a unit of energy.

IAEA

International Atomic Energy Agency.

IEA

International Energy Agency.

kWe

Kilowatt electric.

kWh

Kilowatt hour, One thousand watt hours equal to 3,600,000 joules.

Levelised cost

Levelised cost spreads total generation cost over total output to arrive at a figure which, if charged for each kWh, would exactly balance costs and income.

Load factor

A ratio of the energy that is produced by a facility during the period considered to the energy that could have produced at maximum capacity under continuous operation during the whole of that period.

LWR

Light-Water Reactor.

MWe

Megawatt electric; equals 1,000 kWe.

NEA

Nuclear Energy Agency.

NEEJEC

New Japan Electric Consultant.

OECD

Organization for Economic Co-operation and Development.

O&M

Operation and Maintenance.

PFC

Pulverized Fuel Combustion.

PHWR

Pressurized Heavy Water Reactor.

PWR

Pressurized Water Reactor.

Reprocessing

A generic term for the chemical and mechanical processes applied to fuel elements discharged from a nuclear reactor. The purpose is to remove fission product and recover fissile (uranium-233, uranium-235, plutonium-239), fertile (thorium-232, uranium-238) and other valuable materials.

Spent fuel

Irradiated fuel units not intended to for further reactor service.

Waste management

All activities, administrative and operational, that are involved in the handling treatment, conditioning, transportation, storage, and disposal of waste.

U.S. mill

A unit of currency. One-tenth of U.S. cent (U.S. $ 0.001).

APPENDIX C. LIST STANDARD CONVERSION

1 Btu	= 1.055 KJ
1 KJ	= 1,000 Jouls
1 Kilometer	= 1,000 meters
1 kWh	= 3,413 Btu
1 long ton	= 1.0160 metric tons
1 metric ton	= 1.102 short tons
1,000 MWe	= 6.6 billion kWh (operating with 75% capacity factor)
1 short tons	= 0.907 metric tons
1 Year	= 8,760 hours

APPENDIX D. BASIC ASSUMPTIONS APPLIED TO COST CALCULATIONS

1. Common assumptions to all generating options

- Base date of currency value	1st July 1991
- Discount rate in constant money	10 percent per annum.
- Date of commissioning	1st July 2000

2. Applied only to nuclear and coal-fired power plants

- Operating life time	30 years variants 25 and 40 years.
- Settled-down load factor	75 percent Variants 65 and 80 percent.

- Operating time of units in full power operating hours

Settled-down Load Factor (%)	65	75	80
First Year of Operation	5000	5000	5000
Second Year of Operation	5700	6000	6000
Third and Subsequent Years of Operation	5700	6600	7000

3. Discounted levelised load factor and discounted amount of operating time at the date of commissioning.

At a discount rate of ten percent per annum.

- Total operating hours for ten years.	63,209 hours.
- Operating hours per year	6,391 hours/year.
- Levelised load factor	73 percent.

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